THE HISTORY OF ASTRONOMY.

GR III
BRITISH MUSEUM

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THE HISTORY OF ASTRONOMY,

WITH ITS APPLICATION TO

GEOGRAPHY, HISTORY, AND CHRONOLOGY;

Occasionally Exemplified by the

GLOBES.

Καθαρμοὶ Ψυχῆς Λογικῆς εἰσιν αἱ Μαθηματικαὶ Ἐπιστῆμαι. HIEROC.

By GEORGE COSTARD, *M. A.*
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MDCCLXVII.



CHRONOLOGY,

OR THE

HISTORY

OF THE

TO

THE RIGHT HONOURABLE

The EARL of MORTON,

PRESIDENT of the ROYAL SOCIETY.

MY LORD,

THE following TREATISE is entirely of an Elementary Nature; and was designed to excite Young Persons of Fortune and Leisure to improve their Minds, by a proper Cultivation of such Branches of Knowledge, as they will find both useful and ornamental.

As

As Your Lordſhip, upon a ſight of theſe Papers in Manuſcript, was pleaſed to think they might anſwer the End propoſed: they now beg leave to ſhelter themſelves under Your Patronage and Protection.

Your Lordſhip's Readineſs to encourage all ſuch as deſire to become uſeful, and the Station in which you ſo worthily preſide, are my Motives for this Addreſs; at the ſame Time that they afford me an Opportunity of declaring to the World, the great Eſteem and Regard, with which I have the Honour to be,

My Lord,

Your Lordſhip's moſt obedient,

and moſt humble Servant,

G. COSTARD.

PREFACE.

THE following Sheets owe their Riſe to an accidental Converſation, in which one of the Company, who for ſome Years had been a very eminent Tutor, declared, that he much doubted whether he could then ſolve one Problem on the Globes. This appeared, at that Time, very extraordinary; as the Gentleman was known to have lectured his Pupils on the Globes. However, upon a little Recollection, it did not ſeem ſo hard to be accounted for, as was at firſt apprehended.

Problems, he, no doubt, in this Caſe, conſidered only as Things *to be done*, without attending to the Reaſons *why* they were *ſo done*. And as the Pupils would conceive of Problems in the ſame manner, they would, of Courſe, ſoon forget, what they had *ſeen done*. This was thought to be worthy of ſome Conſideration.

And the moſt likely Method to prevent for the future, what had happened, ſeemed to be, the giving, along with the Problem, the Uſe to which it might be applied; which it was imagined, would not only imprint the Problem ſtronger on the memory, but likewiſe make the Globes ſomething more than mere Matter of Amuſement.

A number of disjointed Problems, however, with their Uſes,

Uſes, would, even then, it ſeemed, loſe much of the entertainment they were intended to convey, and, perhaps, of the Inſtruction too. The proper Remedy for which, appeared to be the connecting them together in the eaſieſt and ſimpleſt manner: But this would be a Work of much Labour and Difficulty.

After trying ſeveral Plans and rejecting them, after altering many Things, enlarging ſome and contracting others, the whole was at length reduced into the Form under which it now appears. The Author preſumes his Work to be the firſt of the kind, and hopes it will prove beneficial to Students, for whom it was chiefly intended.

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THE

BRITISH MUSEUM

THE HISTORY OF ASTRONOMY,

WITH ITS APPLICATION TO GEOGRAPHY and CHRONOLOGY,

Occaſionally illuſtrated by the Globes.

PART I.

INTRODUCTION.

CLEOMEDES, an author but little known, is ſuppoſed to have wrote not long before the beginning of the Chriſtian æra. His treatiſe, called *Cyclicotheoria*, is divided into two parts. In the firſt, he treats of the doctrine of the Sphere, as it was taught in his time; in the ſecond, of the periods of the Planets, the magnitude of the Sun and Moon, their diſtances from the Earth, and their Eclipſes.

This treatiſe then may be looked upon as the foundation of all our preſent *Geography* and *Aſtronomy*, and is extracted, as he acknowledges himſelf, from the writings of *Pythagoras*, *Eratoſthenes*, *Hipparchus*, and *Poſidonius*; names well known, and greatly celebrated among the ancients.

But as both theſe ſciences have received large improvements ſince the time of *Cleomedes*, it will be of ſervice to inquire not only *what* thoſe improvements are, but *when* made, by *whom*, and to *what uſes* they are, or may be, applied.

For by this gradual deduction, we ſhall not only be led to expreſs our gratitude to the memory of thoſe from whom we have received advantage, but ſhall likewiſe diſcern, in what manner each diſcovery paved the way to what followed; and upon the whole, by what eaſy ſteps, through the revolution of ſo many thouſand years, theſe very uſeful ſciences have proceeded towards that perfection they are now arrived at.

But as bare continued hiſtorical narration may ſoon grow ſpiritleſs and tire, it will be proper to exemplify theſe diſcoveries, as we go along, and in ſome ſort ſubject them to view. For,

Segnius irritant animos demiſſa per aures
Quam quæ ſunt oculis commiſſa fidelibus.

To begin then:

GEOGRAPHY

is a ſcience that treats of the exterior ſurface of the earth, as compoſed of land and water: but eſpecially of land.

The land may be conſidered as diſtinguiſhed into mountains, vales, plains, capes, promontories, &c. and the water as divided into oceans, ſeas, lakes, rivers, &c. But theſe are ſo well known, as to make it needleſs to enter into any particular account of them.

As to the internal conſtitution of the earth, or what relates to mines, minerals, and the like, all this belongs to Natural Hiſtory: And the manners, government, temper, &c. of particular people, or countries, relate to Civil Hiſtory: But neither of theſe make any part of *Geography*, properly ſo called.

To enter into any detail of the neceſſity and uſefulneſs of *Geography* to every gentleman, whether as a *Stateſman*, or a *Scholar*, would be but miſpending time, becauſe it is ſufficiently proved by, the beſt inſtructor, every day's experience.

But the knowledge of *Geography* is the knowledge of *Maps* and *Globes*, where countries, ſeas, rivers, and principal places, are marked in the ſame relative ſituation that they bear to each other upon the Earth.

The firſt writer on *Geography*, according to *Strabo*,* was *Homer*. He was followed by *Thales*, and afterwards by *Anaximander*, who (according to *Strabo*,† and *Diogenes Laertius*,)‡ made the firſt Map.

Who made the firſt *Terreſtrial Globe* is unknown; but *Strabo*,§ mentions one made by *Crates*. There was a philoſopher of this name,

* Pag. 13. † Pag. 13. ‡ In his Life, edit. *Amſtel.* § Pag. 177.

contemporary

contemporary with *Euclid*, the author of the *Elements*, about the year before *Chriſt* 300: Yet whether this is the perſon meant by *Strabo*, is uncertain.

It is poſſible that ſome may be ready enough to allow the uſefulneſs of *Geography*, without conceiving an *equal*, or indeed *any* neceſſity for *Aſtronomy* at all. They may think, *quæ ſupra nos, nihil ad nos*; and that it is at beſt only indulging a needleſs curioſity.

However, beſides other uſes that we ſhall perceive as we go along, we may apply with great emphaſis, to *Aſtronomy* in particular, what the great Lord Chancellor *Bacon* obſerved long ago*, of philoſophy in general; that however "a ſmattering in it may incline mens minds "to atheiſm, yet depth of philoſophy, (eſpecially this part of it) "bringeth mens minds about to religion," by convincing them, in the ſtrongeſt manner, of the wiſdom, power, and goodneſs, of the author of the univerſe.

This is the moral or religious uſe that may be made of this Science. And how far it may be of ſervice in preventing the effects of ignorance and ſuperſtition, may be learnt from this memorable inſtance. In the firſt year of the Peloponneſian war, when the Athenian fleet was ready to ſail, there was a very great Eclipſe of the Sun, which ſo terrified the people, that *Pericles*, the commander of that expedition, was obliged to explain to them, what he had learnt from his maſter *Anaxagoras*, concerning the general nature of Eclipſes, particularly thoſe of the Sun; which at that time were but little underſtood.

And on the other hand, what uſe the famous *Chriſtopher Columbus* made of his knowledge of Eclipſes, in working upon the minds of the Americans, is well known. For being in want of proviſions, which that people refuſed to ſupply him with, he threatened them with the anger of heaven, which would ſoon appear, he told them, by the Sun's loſing his light.

And in much later times than theſe we are now ſpeaking of, in order to quiet the minds of ſome ſuperſtitious people, greatly alarmed at the appearance of *Venus* in the day time, and while the Sun was up, Dr. *Halley* compoſed a ſmall piece, publiſhed in the *Philoſophical Tranſactions*†, to ſhew that this was nothing extraordinary, and might be expected every eighth year.

But beſides the uſes already mentioned, we ſhall find that *Aſtronomy* is ſo intimately connected with *Geography*, that, without it, this laſt would

* Eſſay VI. † No. 349.

be very lame and imperfect. This was obſerved long ago by *Hipparchus*. "For we ſhould not know, (ſays he) whether *Alexandria* in *Ægypt*, "lay north or ſouth of *Babylon*, nor how far they are aſunder, was it "not for our knowledge of *Climates*. Nor would any one know, with "certainty, whether places lie eaſt or weſt of each other, unleſs by com-"paring together *Eclipſes* of the *Sun* and *Moon* *."

The word *Climate*, or *Clime*, in common language, and ſo likewiſe among the poets, bears no very preciſe and determinate meaning, being frequently uſed for country in general; but in the ſenſe of the ancients, it means a tract on the ſurface of the Earth, included between two parallels of latitude, where the length of the longeſt day in one, exceeds the longeſt day in the other, by half an hour.

But though *Ptolemy*, the author of the *Syntaxis*, and the Arabian, and other Geographers in general that ſucceeded him, diſtinguiſhed the latitudes of places by the climates they are in, yet this method hath, ſince the revival of learning in Europe, been neglected, as being of little uſe.

In what manner, however, theſe may be found, will be ſeen hereafter.

Now *Aſtronomy*, as we ſhall ſee, will not only be of ſervice in fixing *remote diſtances*, but likewiſe in ſettling the dates of *remote tranſactions*. The truth of *Hiſtory* therefore, and *Chronology*, depends upon *Aſtronomy*: And as *Geography* doth ſo too, we learn the intimate connection that there is between all four of them.

Beſides this, the ancients diſtinguiſhed their times for ploughing, ſowing, ſailing, and taking phyſick, by the riſing and ſetting of certain ſtars and conſtellations. A general knowledge of theſe, at leaſt, will therefore be neceſſary, not only for underſtanding their writers *de Re Ruſtica*, but likewiſe their hiſtorians, poets, and phyſicians.

From this laſt conſideration it appears, of what vaſt conſequence it will be to acquaint ourſelves with the *Celeſtial*, as well as *Terreſtrial* Globe, there being ſuch an intimate dependance of one upon the other.

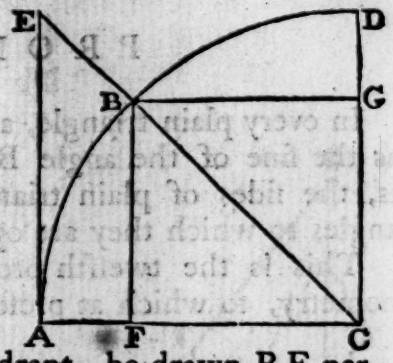
But as Celeſtial Globes repreſent only the *apparent motion* of the heavens, and heavenly bodies, if we would rectify ſuch *falſe ideas* as theſe may convey to us, we muſt compare them with ſuch other machines as ſhall repreſent their *true motions*.

And in order to do this, it will be proper to lay down a few preparatory propoſitions, the application of which will be ſeen as we proceed.

* *Strabo*, pag. 14.

PROPOSITION.

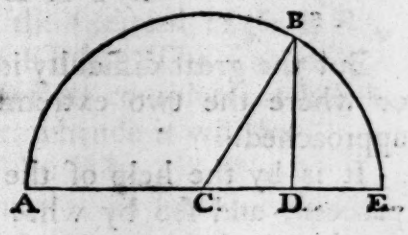
PROPOSITION I.



If with the center C and the diſtance A C be deſcribed the quadrant of a circle A B D, and from the point A be drawn the perpendicular A E, meeting the line E C drawn from the center C, in the point E, the line A E will be the tangent of the arch A B, and the line E C will be the ſecant of the ſame arch.

If from the point B in the limb of this quadrant, be drawn B F perpendicular to the line A C, the line B F will be the ſine of the arch A B, or the angle B C A. And F C equal to B G drawn from the ſame point B perpendicular to C D, will be the coſine of the ſame arch A B, or angle B C A.

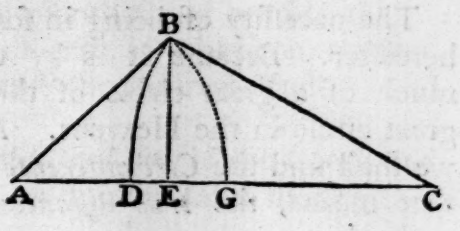
PROPOSITION II.



Thus B D, the ſine of the angle B C E, is likewiſe the ſine of angle B C A. But the angle B C A is the complement of the angle B C E to 180 degrees. Therefore the ſine of any angle is likewiſe the ſine of the complement of that angle to 180 degrees.

PROPOSITION III.

In every plain triangle every angle will have a ſine.



For if in the triangle A B C, with the center C, and the radius B C, we deſcribe the arch B D, and let fall from B the perpendicular B E, the line B E will be the ſine of the arch B D, or the angle B C D.

In

In the ſame manner, if with the center A, and the radius A B, another arch of a circle be deſcribed through B, cutting the ſide A C in G, the line B E will be the ſine of the angle B A E.

PROPOSITION IV.

In every plain triangle, as A B C, the ſide A B will be to the ſide B C, as the ſine of the angle B C A to the ſine of the angle B A C. That is, the ſides of plain triangles are to each other, as the ſines of the angles to which they are oppoſed.

This is the twelfth propoſition of *Keill*'s Elements of Plain Trigonometry, to which at preſent I refer for its demonſtration.

As the meaſuring of diſtances is a part of *Geography*, we muſt obſerve, that diſtances may be of *two ſorts*, *Acceſſible* or *Inacceſſible*. In the former of theſe, the two extremities of the line to be meaſured may be come at, and therefore it may be meaſured by a line, rod, &c. In this therefore we ſhall find no difficulty; and the method of meaſuring ſuch diſtances, may, for diſtinction ſake, be called the

DIRECT METHOD.

But the great difficulty is in meaſuring ſuch diſtances as are *inacceſſible*, or where the two extremities of the line to be meaſured *cannot* be approached.

It is by the help of the two laſt propoſitions only, that we can now proceed, and ſee by what method any *inacceſſible diſtance* may be meaſured. And this again, for diſtinction ſake, may be called the

INDIRECT METHOD.

The neceſſity of being in ſome ſort acquainted with this, will appear hereafter. Becauſe it is by this method only that we diſcover, how much of a great circle of the Earth, correſponds with a *Degree* of a great circle in the Heavens. And from thence again, as will be proved, we ſhall find the *Circumference* of the Earth, and its *Diameter*, and, by that means, the *true diſtances* of the *Planets* from the *Sun*, and from *each other*.

The uſe and importance therefore of this Problem, both in *Geography* and *Aſtronomy*, is very great.

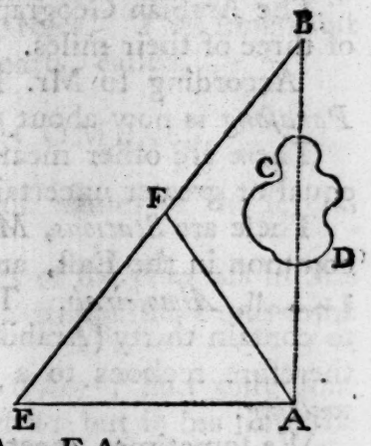
But

But in reducing this Problem to practice, it will be previouſly neceſſary to be furniſhed with ſome inſtrument proper for the meaſuring of angles.

And now we may proceed to the

PROBLEM

itſelf.



Let A B be any diſtance whoſe meaſure is required, but inacceſſible on account of ſome river, lake, or moraſs, &c. as C D.

Let the line A E, taken at pleaſure, be meaſured. And at A take the angles E A F and F A B, and at E the angle F E A. There will then be given (by Elem. I. Prop. XXXII.) the angle E F A, the complement of E A F and F E A to two right angles, and the ſide E A oppoſite to it. And therefore by Prop. IV. here.

Sin. E F A : Sin. F E A :: E A : F A.

Therefore F A will be given. But in the triangle F A B there is given the angle F A B by obſervation, and likewiſe the external angle E F A, and therefore there will be given the angle F B A. The ſine of the angle B F A is likewiſe the ſame with the ſine of its complement E F A, (by Prop. II. here) and therefore known, from whence it will be

Sin. F B A : Sin. B F A : : F A : B A.

Therefore the diſtance ſought B A will be known, in ſuch meaſure as E A was taken in, whether of feet, yards, or miles.

It will not be improper here to obſerve, that in caſes that require accuracy, great care muſt be taken, both in the meaſure of the angles, and in that of the ſide E A. For errors, how ſmall ſoever, when they come to be multiplied into each other, produce a quantity very conſiderable.

It will likewiſe be proper, frequently to obſerve, in what country feet, yards, or miles, the meaſure is taken; becauſe the German, Italian, and Engliſh miles differ conſiderably.

The Engliſh and French foot likewiſe differ, and ſo did the Greek and Roman formerly. Nay, the Roman foot, as appears from monuments yet extant, at different ages was different.

Hence likewiſe not only the Greek and Roman *Stadium* were different, but the Roman *Stadium*, at different times, and it may be in different places,

places, was different. In *Strabo*'s days there were commonly reckoned eight *Stadia* to a Roman mile; and yet that measure was not constant*.

After the Greeks became acquainted with the Persian affairs, we find frequent mention made of a kind of measure called فرسنگ, a *Parasang*. This contained, according to *Herodotus*†, thirty *Stadia:* But this must be unavoidably ambiguous, till we know the true measure of the Greek *Stadium*, by which, it is most probable, *Herodotus* computed.

The Arabian Geographers, as *Abulfeda*, make the *Parasang* to consist of three of their miles. But the Arabian mile is not accurately known.

According to Mr. *Fraser*, in his Life of *Kouli Kân*‡, the Persian *Parasang* is now about *four* English miles.

There are other measures mentioned by authors, which labour under equal or greater uncertainty with those already mentioned.

These are *Stations*, *Mansions*, *Days Journeys*, and the like. They are common in the East, and by the Arabs called المرحلة, *Almarhalat*, and المسيرة, *Almoseirah*. The Nubian Geographer *Al Idrisi*§, determines it to contain thirty (Arabian) miles. But *Abulfeda* leaves it uncertain; and therefore reckons to a *Mansion* eight *Parasangs, at a moderate rate of walking*.

We sometimes meet with, in *Al Idrisi*, *Abulfeda*, and other Arabian Geographers, a measure, which is the largest of all; and that is, المهجري, *Almigri*, which is defined to be, ما يقطعه المركب في يوم والليلة, *as much as a ship can sail in a day and a night*. This must, from the nature of things, be very uncertain, though *Al Idrisi* fixes it to one hundred (Arabian) miles‖.

We had this same measure long before them in *Herodotus***, who says, that the *Arabian Gulph* was forty days sail in length, ειρεσιη χρεωμενω, *with oars*, and, where broadest, half a day's sail over.

But as there is no allowance made here for the difference of men's strength, for contrary winds and tides, *&c.* this measure must be very uncertain and precarious.

The method of measuring inaccessible distances, given above, supposes at least that the two extremities of the line to be measured may be seen from the same place; consequently this method fails when the places whose distance is to be measured are separated by wide seas, as the *Caspian*, *Euxine*, and *Mediterranean* seas.

* See his Geograph. pag. 497. † Pag. 90, and 305. ‡ Pag. 4. § Clim. 5, sect. 1.

‖ See *Greave*'s Pref. to *Abulfeda*'s Tables of *Chorasm*, *&c.* in *Hudf. Geog. Min.* vol. iii. ** Pag. 92.

In

In this caſe recourſe muſt be had to ſome other method, as by obſerving a ſtar or ſome phenomenon in the heavens viſible at both places; and how, in ſuch a manner as this, ſuch remote diſtances may be meaſured, will be ſeen hereafter. In the mean time,

We may proceed to take notice of ſuch circles as are common to both Globes.

Theſe are, in the firſt place, the wooden frames in which they hang, and on which are deſcribed ſeveral concentric circles. The innermoſt of theſe circles is divided into thirty-two equal parts, called,

RHUMBS, OR POINTS OF THE COMPASS.

Theſe points likewiſe have the Latin or Greek names of the ſeveral winds blowing from them affixed to them

Who was the firſt perſon that divided the points of the compaſs in this manner is unknown; but probably it was not till navigation came to be improved, and long voyages undertaken by ſea.

The ancients in *Homer*'s time, according to *Pliny**, had only four points. Afterwards, he ſays, they reckoned twelve: but in his time the common diviſion was into eight points; the former diviſion into twelve points being thought, as he tells us, too *minute*†.

The earlieſt diviſion, therefore, of the Horizon known to the ancients was only into the four cardinal points, as they are now called, *i. e. Eaſt*, *Weſt*, *North*, and *South*; and winds were ſaid to blow from that point to which they were neareſt. Thus the *Eaſt wind* is ſaid to "have brought the *locuſts* into *Egypt*‡;" but more properly, perhaps, the *North-eaſt wind*, called, however, the *Eaſt*, becauſe that was the neareſt cardinal point.

The like ſeems to have been the caſe, where it is ſaid, that the "Lord "cauſed the ſea to go back by a ſtrong *Eaſt* wind.§"

The *Syriac Verſioniſt* ſeems to have ſeen the impropriety of ſuppoſing it to have been ſtrictly an *Eaſt* wind; and therefore he renders the *Heb.* רוח קדים by *a burning wind*, from another ſenſe of the word קדים *kadim*, becauſe *Eaſt* winds in thoſe countries were frequently *burning winds*; ſuch as, perhaps, deſtroyed *Sennacherib*'s army||.

Theſe kinds of winds are ſometimes felt at ſea, blowing from land, and are called by the ſailors *Blooms*. "One afternoon, (ſays Captain "*Dampier*, in his voyage round the world,**) about the 19th of Ja-

* Natural Hiſt. lib. ii. ch. 47. † See *Martin*'s *Virgil*, 8vo. pag. 336. ‡ *Exod.* x. 13.
§ *Exod.* xiv. 21. || *Iſai.* xxxvii. 36. ** Vol. i. pag. 330.

" nuary 1683, in the latitude of 37° ſouth, we felt a briſk gale coming " from off the coaſt of *America*, but ſo *violent hot*, that we thought it " came from ſome burning mountain on the ſhore, and was like the " mouth of an oven.

" Juſt ſuch another gleam I felt one afternoon alſo, as I lay at anchor " at the *Groin*, in July 1694. It came with a ſoutherly wind. Both " theſe were followed by a thunder ſhower."

In the next place are drawn two Calendars, with the names of the months, and the reſpective days of the month. The outermoſt is according to the

JULIAN ACCOUNT.

The other according to the *New Stile*, or

GREGORIAN ACCOUNT.

Between theſe are delineated the twelve ſigns of the Zodiack, with their names and aſtronomical marks, in order to find the Sun's place in the Ecliptick, and for the reſolving all ſuch problems as may depend upon it.

This wooden frame is ſometimes called the HORIZON, becauſe it ſerves indifferently to repreſent the Horizon of every place; and the uſe of it then is, to determine the *altitude*, *azimuth*, and *amplitude* of the Sun, Moon, and Stars, the times of their riſing and ſetting, and the length of their *diurnal* and *nocturnal* arches.

The Horizon is of two ſorts,

THE SENSIBLE HORIZON AND THE RATIONAL HORIZON.

THE SENSIBLE HORIZON

is that circle which is formed by rays drawn every way from the eye of the ſpectator, as a center, wherever he ſtands, and comprehends all that ſpace which he ſees round about him.

Or, in other words, it is all that ſpace that we ſee round about us, terminated by the heavens, where they ſeem to touch the earth.

The Senſible Horizon, therefore, may be conceived as the plane of a circle touching the earth, the center whereof is the place where we ſtand, and infinitely extended every way to the heavens.

THE

The RATIONAL HORIZON

is a great circle that may be ſuppoſed to be drawn parallel to the Senſible Horizon, paſſing through the center of the Earth, and conſequently dividing that and the Heavens into two equal parts, or Hemiſpheres.

The Wooden Horizon, which lies in the plane of the Rational Horizon, or coincides with it, ſerves likewiſe to repreſent the Senſible Horizon; that is, the Horizon of every place indifferently.

This may, and ſometimes doth, appear a difficulty. But that will eaſily be ſatisfied, by conſidering the following

PROPOSITION V.

The apparent diameter of ſmall objects decreaſeth as the diſtance of the object from the eye increaſeth.

Let A B be a ſmall object ſeen by the eye at D, under the angle A D B, and at E, under the angle A E B.



The apparent diameter of the object A B to the eye at D, will be to the apparent diameter of the ſame object to the eye at E, as the diſtance E B is to the diſtance D B.

DEMONSTRATION.

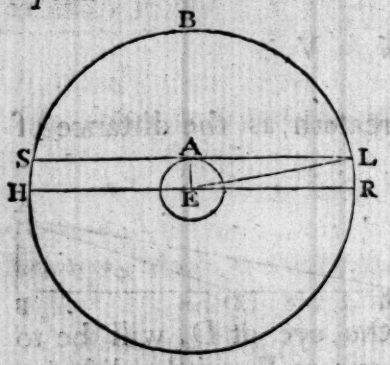
In the triangle E A D, the ſide A D is to the ſide A E as the ſine of the angle A E D is to the ſine of the angle A D E (by Prop. IV.) But the ſine of the angle A D E is the ſame with the ſine of its complement A D B; therefore the ſide AD is to the ſide AE, as the ſine of the angle A E D to the ſine of the angle A D B. But becauſe the object A B is ſmall (by Hypoth.) the ſide A D will not ſenſibly differ from D B, nor the ſide A E from EB; therefore D B will be to E B as the ſine of the angle A E D, or AEB, to the ſine of the angle A D B. But in ſmall angles, the ſines of angles are as the angles themſelves; therefore D B is to EB as the angle AEB is to the angle ADB, or ADB : AEB : : EB : DB. But the apparent diameters of objects are as the angles under which they are ſeen; and therefore the angle A D B is as the apparent diameter of the object A B when ſeen at D, and A E B as the apparent diameter of the ſame object AB when ſeen at E. Therefore the apparent diameter of

the object A B, to the eye at D, will be to the apparent diameter of the ſame object at E, as the diſtance E B is to the diſtance D B.

W. W. D.

But the apparent diameters of objects, however large, when ſeen at a vaſt diſtance, appear ſmall; and if that diſtance be yet farther *increaſed*, the apparent diameter of the ſame object will, by the Propoſition, be proportionably *decreaſed*.

Therefore if the diſtance be *increaſed* in ſuch a manner that it may be looked upon as *infinite*, the apparent diameter of the object, ſeen from thence, will be *infinitely decreaſed*; that is, it will appear no bigger than a *point*.



But ſuch is the diameter, or ſemidiameter, of the earth E A, when viewed from the orb of fixed ſtars H S B L R; therefore the angle ALE vaniſhing, becauſe AE vaniſhes, or becomes = o, it makes no difference whether an object, as a fixed ſtar at L, be viewed from the center of the earth at E, or from the ſurface of it at A; that is, the *Senſible Horizon* S L will coincide with the *Rational Horizon* H R. And therefore the *wooden frame* in which the Globe hangs, whoſe plane coincides with the plane of the *Rational Horizon*, repreſented here by H R, ſerves indifferently to repreſent the plane of the *Senſible Horizon* of any place, here denoted by S L.

The other Circle in common to both Globes is the Braſs Ring, in the plane of which lies the axis about which they turn, and is called the

MERIDIAN;

becauſe when the Sun's place in the Ecliptick is brought up to the eaſtern ſide of it, it is ſuppoſed to be *mid-day*, or noon. And when any place, on the other Globe, is brought up to the eaſtern ſide of this ring, it is then *mid-day*, or noon, at that place in particular, and, in general, to all other places that lie under it at the ſame time.

As the heavens, by their apparent motion, turn round the earth in twenty-four hours, or, which is the ſame thing, every place on the Earth's ſurface, by its real motion, deſcribes a circle, therefore the laſt circle in common to both Globes, to be here taken notice of, is that fixed at the North Pole of each Globe, called the

HOUR

HOUR CIRCLE.

This is divided into twice twelve hours, which the index fixed to the axis of the Globe, by its revolution, ſucceſſively points to, and is uſeful upon a variety of occaſions, as will be ſeen hereafter.

Having thus taken a view of thoſe circles that are common to both Globes, we may now proceed to thoſe that are peculiar to each.

To begin then with the Celeſtial Globe.

A CELESTIAL GLOBE

is that on which the Aſteriſms, or Conſtellations, are delineated.

How early the ancients had any thing of this kind is uncertain. For what was the Sphere of *Atlas*, mentioned by *Diodorus Siculus**, or that of *Muſeus*, by *Diogenes Laertius*†, is not at all clear, nor indeed the time when theſe perſons lived. The poem which we have, extant under the name of *Muſeus*, is plainly the work of ſome later *Greek*, as may be ſeen proved by *Cauſabon*'s note on the laſt cited place.

Palamedes, who lived at the time of the Trojan war, as it is ſaid,

Εφεῦρε δ' Ἀστρων μέτρα καὶ Περιτροφὰς,
Τάξεις τε τἀνέμων, ὑρανία τε Σήμαλα. *Sophocl. in Nauplio.*

To mark the ſigns that cloudleſs ſkies beſtow,
To tell the ſeaſons when to ſail and plow,
He firſt devis'd; each planet's order found,
Its diſtance, period, in the blue profound.

In *Simplicius*'s Comment on *Ariſtotle de Cælo* ‡, there is mention made of the Spheres of *Calippus*, *Eudoxus*, *Autolycus*, and *Soſigenes*; but what was the nature of them is unknown, as they are no where deſcribed by the ancients.

And among other ornaments carried away by *Lucullus*, when the Romans took *Sinope*, a city of *Pontus*, *Strabo* ſays §, was the Sphere of *Billarus*. This was about eighty years before *Chriſt*; but what was the nature of that Sphere is uncertain.

From *Pliny* ‖ it ſeems as if *Hipparchus* had a Celeſtial Globe with the ſtars delineated upon it. How many aſteriſms were drawn on this, or

* Pag. 193. † Pag. 3. ‡ Lib. ii. § Pag. 822. ‖ *Nat. Hiſt.* lib. ii. c. 26.

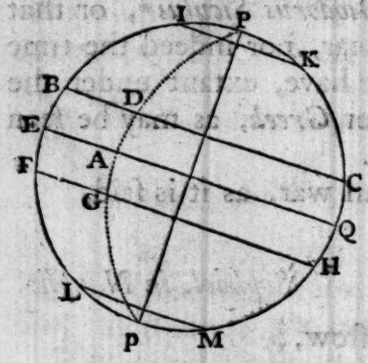
any

any of the Celeſtial Globes of the ancients, is uncertain. Probably they were few at firſt, and afterwards more; for the aſteriſms were not all form'd at once. *Homer* doth not mention the *Little Bear*; and the reaſon (ſays *Strabo**,) is, becauſe it was not formed in his time.

In *Ptolemy*'s Catalogue, the compleateſt, that is left us, of the *Greeks*, there are *forty-eight* conſtellations; but there are others that have been formed ſince, and are now delineated on the preſent Globes. *Ptolemy*'s aſteriſms, however, are eaſily diſtinguiſhed from theſe, the ſeveral ſtars which compoſe them being marked with the letters of the Greek and Roman alphabets.

Theſe letters are called *Bayer's Letters of Reference*, being the contrivance of a perſon of that name, about A. D. 1603, and are uſeful for deſcribing the path of a comet in the heavens, or marking the place of a *new ſtar*, or any other phenomenon.

In the Celeſtial Globe



The points P and p are the Poles of the Circle E Q here repreſented as a right line, and called

THE EQUATOR.

Which is that great Circle, parallel to which the whole Heavens ſeem to turn round in twenty-four hours.

The Equator divides the Heavens into two equal parts, called,

NORTHERN AND SOUTHERN HEMISPHERES.

P is the North Pole, p the South Pole, and the line P p the axis of the Sphere.

All circles conceived to paſs through the poles of the ſphere, as P A p, or P E p, interſecting the Equator at *right angles*, are, with reſpect to any point in the heavens, called,

HOUR CIRCLES, OR CIRCLES OF ASCENSION;

becauſe the aſcenſion of the heavenly bodies from a certain point are determined by them.

All circles, as B C, parallel to the Equator, are, with reſpect to any point in the heavens, called,

* Pag. 6.

PARALLELS

PARALLELS OF DECLINATION.

The declination then of a ſtar, the Sun, *&c.* is an arch of the Meridian paſſing through them, and intercepted between them and the Equator, as BE, AD, AG, and is either *North*, as AD, or *South*, as AG.

Of the Parallels of Declination, four are diſtinguiſhed by particular names; and they are, in the firſt place, the

TWO TROPICKS,

as BC, FH, which lie on different ſides of the Equator, each diſtant from it, by the eſtimation of the moderns, 23 deg. 29 min.

By the ancients it was made different at different times, which may be owing, perhaps, to the inaccuracy of the inſtruments with which they made their obſervations.

Manilius made it 24 deg. as appears from this line, where he ſays the *Equator*

Quatuor & gradibus ſua ſila reducit ab æſtu. L. i. ver. 579.

And in this, perhaps, he follows the authority of *Eudoxus*. The reaſon of this proportion is, becauſe though now every circle is ſuppoſed to be divided into 360 parts, or degrees, yet *Eudoxus*, and other mathematicians, divided the circumference of circles into *ſixty* parts only; therefore it will be $60^{\circ} : 360^{\circ} :: 4^{\circ} : 24^{\circ}$.

BC is called the Tropick of *Cancer*, and FH the Tropick of *Capricorn*, becauſe, originally, the tropical points were in the aſteriſms called *Cancer* and *Capricorn*.

The other Parallels of Declination, particularly diſtinguiſhed, are the

POLAR CIRCLES,

as IK, LM.

Theſe are placed by the moderns, likewiſe, at the diſtance of 23 deg. 29 min. from each Pole; the ſame with the diſtance of the Tropicks from the Equator.

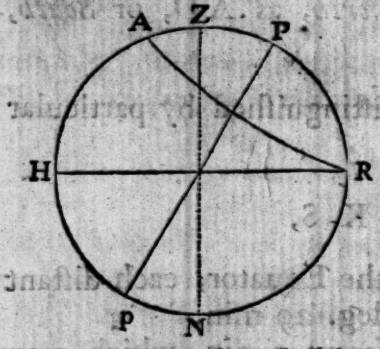
The firſt perſon that fixed the Polar Circles to a conſtant diſtance from the Poles (according to *Scaliger**,) was *Johannes à Sacro Boſco*, (*i. e.*

* Epiſt. II.

John

John Holywood, or *Halifax*, becauſe born at *Halifax* in *Yorkſhire*) about A. D. 1230.

The ancients, before that time, always made the Arctick Circle variable, and to touch the horizon of the place in the north part of the meridian.



Let H R be the horizon of any place, P R the height of the Pole there, P p the axis of the Equator, then will A R be the Arctic Circle of that place, according to the manner of the ancients, touching the horizon in the point R.

An example of this we have in *Cleomedes*, who ſays, "that at the "iſland *Thule*, where they ſay the philoſopher *Pytheas* of *Marſeils* was, "it is reported, that the Summer Tropick is intirely above the Horizon, "and that, to the inhabitants there, the ſame is their Arctick Circle."

Where *Thule* lay is not agreed among authors. *Virgil*, in compliment to *Auguſtus Cæſar*, aſks him, among other particulars relating to his heavenly condition,

An Deus immenſi venias maris, ac tua Nautæ
*Numina ſola colant? Tibi ſerviat ultima Thule**.

By the term *ultima Thule*, it ſeems as if this was the fartheſt part of the known world weſtward in the *Auguſtan* age. Let the Globe be rectified according to the circumſtances juſt related from *Cleomedes*, and let the Summer Tropick be made the Polar Circle, according to the doctrine of the ancients, it will appear that *Thule* lay in 66 deg. 30 min. of north latitude, and therefore was probably *Iceland*.

This is ſaid upon ſuppoſition that the *Thule* of the ancients was an iſland. But *Strabo* ſays†, that *Pytheas* only called *Thule* "the moſt northern of the *Britiſh* parts," without mentioning whether it was an iſland or not.

If this be true, then *Thule* may have been only the northern extremity of *Scotland*. Neither the obſervations of the ancients were made with great exactneſs, nor the relations of them delivered with a preciſeneſs to be depended on. The refractions in northern countries are very great, and elevate the Sun and Moon when near the horizon. But *Pytheas* was

* Georg. i. ver. 29. † Pag. 175.

unacquainted

quainted with this; ſo that the elevation of the Pole at *Thule* might not have been ſo great as 66 deg. 30 min.

Manilius, a poet of the *Auguſtan* age, deſcribes this Circle thus *,

Circulus ad Boream fulgentem ſuſtinet Arcton,
Sexq; fugit ſolidas à Cœli Vertice partes.

This laſt line Dr. *Bentley*, in his edition, corrects thus;

Sex è triginta, fugiens à Vertice partes.

The ancients, it ſeems, called the Pole, as it is termed now-a-days, the Vertex of the Heavens; and then the meaning will be, that, according to him, the Polar Circle A R was diſtant from the Pole ſix parts out of thirty; or, in other words, that the arch P R, or the height of the Pole, was ſix of ſuch parts as a Semicircle was ſuppoſed to contain thirty, *i. e.* the height of the Pole, in more modern language, was 36 deg. For $30^{\circ} : 180 :: 6 : 36^{\circ}$

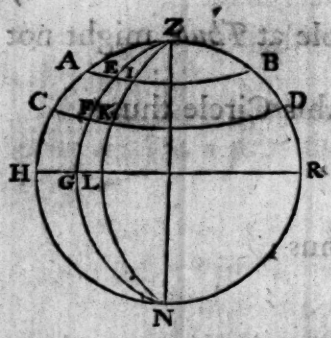
From hence, however, it appears, that this Sphere of *Manilius* is nothing more than the Sphere of *Eudoxus* in *Latin* verſe, which he knew not how to accommodate to the latitude of *Rome*. For *Cnidus*, a city in *Aſia Minor*, where *Eudoxus* lived, lies nearly in latitude 36 deg. north; whereas *Rome*, where *Manilius* is ſuppoſed to have wrote, lies in 41 deg. 54 min.

The point in the Heavens directly over the head of any perſon, as Z, is now called the ZENITH; and the point oppoſite to it, as N, is called the NADIR.

Theſe two terms are nothing more than corruptions of two *Arabic* words; the firſt of سمت *Semt*, which ſignifies a *Point*. In *Al Fergani*'s Elements of Aſtronomy †, it is called سمت راس *Semt Râs*, *i. e.* the *Point of the Vertex*, or the *Vertical Point*.

The other term, *Nadir*, is a corruption of the *Arabic* نظير which ſignifies *ſimilar*, or *alike*, or *oppoſite*. So that نظير السمت *Natheir al-ſemt*, or in one word نظير *Natheir*, or النظير *Al Natheir*, is nothing more than the *Point oppoſite to the Vertex*.

* Lib. i. ver. 564. † P. 20.



Circles, ſuch as AB, CD, that are parallel to the horizon of any place, are called,

ALMACANTERS.

From the Greek word KENTPON, comes, after the Arabic manner of forming participles, مقنطر *Mokenter*, and, in the plural number, مقنطرات *Mokenterât*. The word المقنطر *Almokenter* then is nothing more than a barbarous word, or, as *Quintilian* calls ſuch, *vox hybrida*, partly Greek and partly Arabic, and ſignifies only a Circle having its center in the ſame axis with another.

Becauſe the altitude of objects above the horizon is different, according as they are in one or other of theſe Circles, therefore they are now more commonly called,

PARALLELS OF ALTITUDE.

Theſe are ſupplied, in the uſe of the Globes, by a braſs flexible quadrant, called the QUADRANT of ALTITUDE.

All Circles, as ZGN, ZLN, drawn through the *Zenith* and *Nadir* of any place, are called

VERTICAL CIRCLES.

And thoſe Circles, that paſs through the *Zenith* and *Nadir* of any place, and the Eaſt and Weſt points of the Horizon, are termed

PRIME VERTICALS.

The altitude of objects above the horizon is eſtimated by theſe *Vertical Circles*; and therefore that Vertical Circle which paſſeth through the Zenith and Nadir of any place, and the North and South points of the Horizon, is called

THE MERIDIAN.

And the altitude of any object at that time, and in that Vertical, is called its

MERIDIAN

MERIDIAN ALTITUDE.

An arch of the Horizon, as H G, intercepted between the Meridian H A Z and the Vertical Circle, paſſing through any object, and cutting the Horizon in the point G, is called its

A Z I M U T H.

This word likewiſe is a corruption of the Arabic word السمت *Al-ſemt*, or *Aſſemt*, which ſignifies nothing more than a *point* or *mark*.

That broad Circle in the Heavens, or on the Globe, which contains the the twelve Signs, is called the

Z O D I A C K.

And the reaſon is, becauſe, according to the Chaldean diviſion, it conſiſted only of animal figures; what is now called *Libra* being by them reckoned a part of *Scorpio*, and making the claws of that animal. Hence *Libra* is ſometimes ſtill called *Chelæ*.

From this diviſion it appears, as *Servius* ſays on *Georg.* i. ver. 33. that the Chaldean Zodiack conſiſted only of eleven Signs.

And this will help us to explain the following paſſage of *Virgil*, who, in complement to *Auguſtus Cæſar*, aſks him where he would chuſe to fix himſelf in his heavenly condition.

Anne novum ſidus tardis te menſibus addas
Qua locus Erigonen inter Chelaſq; ſequentes
Panditur. Ipſe tibi jam Brachia contrahit ardens
Scorpius, & Cæli juſta plus parte reliquit.

For the *Scorpion*, according to this diviſion, taking up the ſpace of two Signs, had more of the Heavens than fell to his ſhare.

The diviſion of the Zodiack into twelve parts correſponds with the diviſion of the year into twelve months; and therefore plainly anſwers to the apparent motion of the Sun. There is another broad Circle in the Heavens, not taken notice of by European writers, but much celebrated by all the Arabian aſtronomers. It is divided into twenty-eight unequal parts, correſponding with the Moon's courſe, and therefore called the *Manſions of the Moon*, becauſe the Moon was obſerved by them to be in, or near, one or other of theſe Conſtellations every night. And as this diviſion is different from any thing among the Greeks, it ſeems not to have been borrowed from them, and therefore may be looked on as the remains of very old Aſtronomy.

NAMES OF THE MANSIONS OF THE MOON.

I. الشرطان *Al-ſheratân*, from شرط *ſignum, indicium*, and are the Stars in the horns of the *Ram*.

II. بطين *Botein*, a diminutive from بطن *Betn, venter*, being the Stars in the *Ram*'s belly. They are the ſeventh and eleventh Stars in *Ulugh Beigh*'s table of this Conſtellation.

III. الثريا *Al-thuraiya*, from ثروي *Therwa, Multus, copioſus, abundans*; *i. e.* the *Pleiades*.

IV. الدبران *Al-debarân*, which properly ſignifies *quicquid pone, poſterius, & à tergo eſt*. It means the *Hyades*; ſometimes it is particularly applied to the bright Star called the *Bull's Eye*. Dr. *Hyde* thinks the word aroſe from an ignorance of the Greek language, and that the Arabs took Υάδες to be the plural of Υας, the ſame with Υς, which they imagined to be the poſitive of the comparative and ſuperlative ὑςερος and ὑςατος.

V. الهقعة *Al-hek'ah*, the three Stars in the head of *Orion*.

VI. الهنعة *Al-hen'ah*, according to *Ulugh Beigh*, the Star in the left foot of *Pollux*. By *Bayer* it is marked γ. *Al Fergani* ſays, it is two Stars at a little diſtance from each other, of which the northern one is the brighteſt.

VII. الذراع *Al-dirà*, or ذراع الاسد *Dira al-aſad*; i. e. *Brachium Leonis*. *Al Fergani* makes it the heads of the two *Gemini*; and ſo *Mohammed Tuſæus*, cited by Dr. *Hyde* on *Ulugh Beigh*, in whoſe table of this Conſtellation they are the firſt and ſecond Stars.

VIII. النثرة *Al-néthra*, or انف الاسد *Enph al-aſad*, the *Lion's Noſe*. It is the *nebula* in *Cancer*, and called by the Greeks Φάτνη, *Præſepe*.

IX. الطرفة *Al-terpha*, the *Lion's Eyes*. They are the third and fourth Stars in *Ulugh Beigh*'s table of this Conſtellation, and are in *Bayer* marked μ and ε.

X. الجبهة *Al-gjeb'ha*, the *Lion's Forehead*, or, according to *Al Fergani*, four bright Stars, one of which is the *Lion's Heart*. It is the fifth in *Ulugh Beigh*'s table.

XI. الزبرة *Al-zubra*, two bright Stars, ſays *Al Fergani*, following the *Lion's Heart*. In *Ulugh Beigh*'s table they are the twentieth and twenty-firſt Stars. By *Bayer* they are marked δ and θ.

XII.

XII. الصرفة *Al-ſérpha*, the *Lion's Tail*, according to *Al Ferangi*. It is called *Serpha*, *q. d. Mutatrix*; becauſe when it riſes (ſays the Arab *Turgjeman*) the cold departs, and the heat comes.

XIII. العوا *Al-auwa*, according to *Al Fergani*, the five Stars under *Virgo*, four of them diſpoſed in a right line, and forming a bend towards the Weſt, and ſo reſembling the letter ا *Eliph* in the Arabic alphabet. In *Ulugh Beigh* they are the fifth, ſixth, ſeventh, and tenth Stars.

XIV. سماك الأعزل *Simak al-a'zal*, the *Virgin's Spike*; this is in *Ulugh Beigh*'s table the fourteenth Star.

XV. الغفر *Al-gaphr*; according to *Ulugh Beigh*, it is three Stars in the feet, or rather the ſkirt of the robe of *Virgo*. Three ſmall Stars, ſays *Al Fergani*, at ſome diſtance from each other, two of which are placed before the two *Chelæ* of *Scorpio*. By *Bayer* they are marked φ, ι, κ.

XVI. الزبانا *Al-zubâna*, i. e. *Libra*.

XVII. الأكليل *Al-iclil*, i. e. *Corona*. Three bright Stars lying in a right line, ſays *Al Fergani*; but *Firuzabadi* makes them four. They are the four firſt in *Ulugh Beigh*'s table of *Scorpio*, and are marked by *Bayer* ν, β, δ, π.

XVIII. القلب *Al-kalb*, the *Scorpion's Heart*.

XIX. الشولة *Al-ſhaula*, the *Scorpion's Tail*.

XX. النعايم *Al-naâim*; eight bright Stars, according to *Al Fergani*, four of which lie in the Milky-way, and are called Cattle *(Pecora) going to water*; and four out of it, and are called Cattle *returning from water*. They are the ſeven firſt and the twentieth in *Ulugh Beigh*'s table of *Sagittary*, and marked γ, δ, ε, λ, μ, σ, φ, ψ.

XXI. البلدة *Al-beldah*, which ſignifies a town or city. According to ſome it is ſix Stars in *Sagittary*, where is the Sun's place the ſhorteſt day in the year. According to *Firuzabadi*, it is a part of the Heavens intirely deſtitute of Stars; and with him agrees *Al Fergani*.

XXII. سعد الذابح *Sa'd al-dâbih*, *Fortuna mactantis*. It conſiſts of two ſmall Stars, ſays *Al Fergani*, near the moſt northern of which is placed another dim Star, called by the Arabs a *Sheep*, from whence it derives its name; one might therefore call all three of them together the *Sheep and its Butcher*. The *Turgjeman* ſays, the *Dâbih* conſiſts of four Stars, and that they are in the Sign *Capricorn*. In *Ulugh Beigh*'s table of *Capricorn*, they are his

his first and third Stars. They are marked by *Bayer* α β; and the Star here called a *Sheep* is by him marked γ.

XXIII. سعد البلع *Sa'd al-bula, Fortuna deglutientis.* *Firuzabadi* says, that it consists of two Stars of equal pace with each other, *i. e.* as *Al-Fergani* explains it, *lying in the same parallel.* One of them, says the first of these authors, is a *dim Star*, the other a *bright one*, which, as it were, swallows up the other. *Sa'd-bula* is the sixth Star in *Ulugh Beigh*'s table of *Aquarius*, and seems to be that marked by *Bayer* γ; but, according to *Al Fergani* and *Firuzabadi*, it must be that by him marked μ.

XXIV. سعد السعود *Sa'd al-süûd, Fortuna fortunarum.* Three Stars, says *Al Fergani*, one of which is a bright one; it is in the Constellation *Aquarius.* In *Ulugh Beigh*'s table of that Constellation it is his fourth and fifth Stars. On the Globes the word *Sa'd* is corruptly wrote *Scheat*, and is fixed to *Bayer*'s δ, on the leg of *Aquarius*; but *Sa'd al-süûd* are those marked by *Bayer* β ξ.

XXV. سعد الاخبية *Sa'd al-achbiya, Fortuna Tentoriorum.* Three Stars, says *Al-Fergani*, in the figure of a triangle, in the middle of which is a fourth Star. They are the ninth, tenth, eleventh, and twelfth Stars in *Ulugh Beigh*'s catalogue of the Constellation *Aquarius*, and marked by *Bayer* γ, ζ, η; and the other, by its longitude and latitude, seems to be that in the bend of the body, by him marked θ.

XXVI. الفرغ المقدم *Al-phergh al-mukaddem.* The word فرغ *Phergh* is explained by *Golius* to be, *Locus medius inter ansas urnæ, quo effunditur aqua.* This *Phergh al-mukaddem* is, according to *Al Fergani*, two bright Stars, of which the northern one is called the *Shoulder of Pegasus.* They are the third and fourth Stars in *Ulugh Beigh*'s table of that Constellation, and marked by *Bayer* α β.

XXVII. الفرغ الموخر *Al-phergh al-muáccher.* They are, according to *Al Fergani*, two bright Stars, at a distance from each other, following the *Phergh al-mukaddem.* They are the first and second Stars in *Ulugh Beigh*'s table of *Pegasus*; one is in the head of *Andromeda*, and the other is *Bayer*'s γ, in the extremity of *Pegasus*'s wing.

XXVIII. الرشا *Al-rishà, Funis.* This is not marked at all under this name by *Ulugh Beigh.* In *Al Fergani* this twenty-eighth Manfion is called بتن الحوت *Batn al-hût, Venter Piscis*, and is said

faid to be the Stars of the *Northern Fiſh*. In *Ulugh Beigh* this *Batn al-hût* is his twelfth Star in the table of *Andromeda*, and is *Bayer*'s β in the girdle of *Andromeda*.

The longitudes and latitudes of theſe Manſions are in *Ulugh Beigh* as follow; and where they conſiſt of ſeveral Stars, they are reduced to a Medium.

No.	Longitude.	Latitude.	No.	Longitude.	Latitude.
1	☌. 26°. 40′	7°. 13′½	15	6°. 26°. 44′½	9. 30
2	1. 09. 02½	2. 12′	16	7. 09. 55′	2. 30
3	1. 22. 01	3. 45′	17	7. 26. 16′	5. 27
4	2. 02. 31	5. 15′	18	8. 02. 16′	4. 30
5	2. 16. 31	13. 30′	19	8. 16. 13′	13. 43½
6	3. 01. 31	7. 12′	20	8. 28. 04′	10. 48
7	3. 14. 19	8. 12′	21	0. 00. 00′	00. 00
8	3. 29. 46	1. 00′	22	9. 26. 20′	5. 46
9	4. 13. 16	11. 03′	23	10. 05. 14′	7. 37
10	4. 22. 13	0. 09′	24	10. 16. 11′	7. 46
11	5. 03. 04	15. 27′	25	11. 00. 10′	8. 24
12	5. 13. 49	2. 00′	26	11. 18. 46′	24. 55
13	5. 29. 28	4. 27′½	27	0. 03. 55′	18. 52
14	6. 16. 10	2. 09′	28	0. 23. 13′	25. 36

Theſe Manſions of the Moon are older at leaſt than the time of *Mohammed*; for he ſeems to allude to them, Sur. x. ver. 6. where he ſays, that God السنين جعل الشمس ضيا والقمر نورا وقدره منازل لتعلموا عدد *Poſuit ſolem in ſplendorem, & lunam in lumen, & diſpoſuit eam in ſtationes ut ſciretis numerum annorum.* And ſo the words are explained by *Gelaloddîn*, a famous commentator on the Korân.

The great Circle dividing the Zodiack into two equal parts, in the plane of which the Sun performs his apparent annual revolution round the Earth, is ſtiled

THE ECLIPTICK;

becauſe there can be no eclipſes of the Sun or Moon, but when the Moon is in or near this Circle. It is inclined to the Equator in an angle of about twenty-three degrees and a half; and therefore the poles of theſe

theſe Circles muſt be diſtant from each other by the ſame quantity of twenty-three degrees and a half.

The Ecliptick cuts the Equator in two oppoſite points, called *Aries* and *Libra*; and the diſtance of the Sun in the Ecliptick from the point *Aries*, is called his LONGITUDE.

The places of the Moon and fixed Stars are all of them referred to the Ecliptick; and their places, ſo referred, reckoning from the beginning of *Aries*, are ſtiled their LONGITUDE.

And an arch of a great Circle, paſſing through the Pole of the Ecliptick, and a given Star, intercepted between the Ecliptick and the Star, is its LATITUDE.

A great Circle, paſſing through the Poles of the Ecliptick and the Equator, is called the

SOLSTITIAL COLURE.

And another great Circle, paſſing through the Poles of the Equator and the points *Aries* and *Libra*, and ſtanding at right angles with the former, is called the

EQUINOCTIAL COLURE.

And here we may here introduce the following

PROBLEM,

To find the longitude and latitude of a given Star, and *vice verſâ*.

Bring the ſolſtitial colure to the braſs meridian, and there fix the Globe; then will the Pole of the Ecliptick be juſt under 23 deg. 30 min. accounted from the Pole above the North point of the Horizon, and upon the ſame Meridian: there ſcrew the quadrant of altitude, and then bring its graduated edge to the given Star; then will the Star cut its proper latitude on the quadrant, reckoned from the Ecliptick, and the quadrant will cut the Ecliptick in the Star's longitude, or its diſtance from the firſt point of *Aries*.

Through the Pole of the Equator and any Star may be drawn a great Circle, cutting the Equator in a certain point; therefore bring the given Star to the braſs Meridian, and mark the point of the Equator directly under it; the arch of the Equator intercepted between that point and the beginning of *Aries*, will be that Star's

RIGHT

RIGHT ASCENSION.

And an arch in the braſs Meridian, intercepted between the Equator and the point directly over the Star, will be its

DECLINATION.

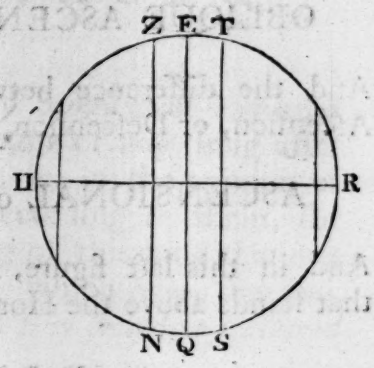
The reaſon why it is called the Right Aſcenſion of the Sun or Star, is, becauſe it is that point of the Equator which riſes along with it in a *Right Sphere*, or comes along with it to the Meridian in an *Oblique Sphere*.

And in order to underſtand the meaning of theſe terms, it muſt be conſidered, that the Earth being ſpherical, places may lie either under the Equator, or under the Poles, or between both. And according as places are thus differently ſituated, the Heavens will appear to turn round the Earth in twenty-four hours in a very different manner.

This firſt figure repreſents what is called

A RIGHT SPHERE;

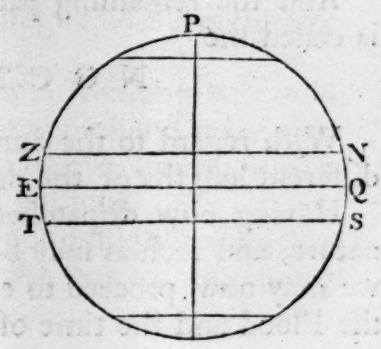
which is the poſition of the Heavens agreeing with all thoſe people that live under the Equator. Here the Poles of the World lie in the Horizon; and the Equator, Tropicks, and Polar Circles ſtand all of them perpendicular to the Horizon. Conſequently to all theſe people the heavenly bodies will always riſe and ſet perpendicularly; their days and nights will likewiſe be equal throughout the whole year.



This ſecond figure repreſents

A PARALLEL SPHERE.

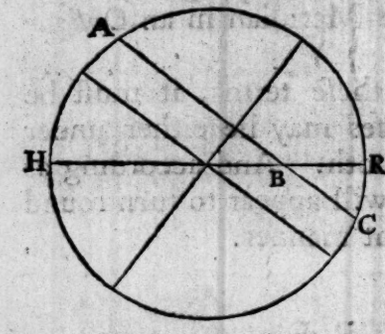
In this poſition of the Heavens the Poles of the World are in the Zenith and Nadir, and the axis of it ſtands at right angles to the Horizon; conſequently the Equator and the Horizon coincide, and the Tropicks and Polar Circles are parallel to both. This poſition of the Heavens agrees to thoſe people that live under the Poles, who will have but one day and night throughout the whole year; and for



the ſame reaſon the Moon, in *half* her monthly revolution, will never *riſe*, and in the other *half* will never *ſet*: the fixed Stars likewiſe will to theſe people deſcribe Circles every day parallel to the Horizon, ſome never *riſing*, and others never *ſetting*.

This third figure repreſents

AN OBLIQUE SPHERE,



in which the Equator, and all the Circles parallel to it, make oblique angles with the Horizon. This poſition of the Heavens agrees to all thoſe people that live neither under the Poles nor under the Equator; and therefore, now an arch of the Equator, intercepted between the beginning of *Aries* and the point *riſing* or *ſetting* along with any Star, the Sun, or Moon, is called the

OBLIQUE ASCENSION, OR OBLIQUE DESCENSION.

And the difference between the Right Aſcenſion and this Oblique Aſcenſion, or Deſcenſion, is called the

ASCENSIONAL OR DESCENSIONAL DIFFERENCE.

And in this laſt figure, the arch of any Parallel of Declination (A B) that ſtands above the Horizon (H R) is called the

DIURNAL ARCH.

And the remaining part of it, which is below the Horizon, as B C, is called the

NOCTURNAL ARCH.

With regard to the Sun's apparent motion, theſe Arches determine the different lengths of the days and nights.

Having now diſpatched ſuch conſiderations as are of a more general nature, and ſuch as may be looked on as preparatory to what is to follow, we may now proceed to enquire into the progreſs of Aſtronomy between the Flood and the time of *Thales*.

THE

PART II.

THE HISTORY OF ASTRONOMY, FROM THE FLOOD TO THALES.

THE Flood is the higheſt that Arts and Sciences of any kind can pretend to go; and the firſt account of any thing after that, which looks like aſtronomical, is, in the opinion of ſome, the *tower of Babel* *, built, according to them, for an *Obſervatory*. But there is nothing of this kind that can be inferred from the hiſtory of that building, which was, ſay our Tranſlators, to make the builders "a *name*, leſt *they ſhould be ſcattered* "*over the face of the earth*."

But others have conjectured, and with good probability, that by the word *Sem*, inſtead of a *name*, is to be underſtood ſomething *elevated*, or a *mark*, which in an open flat country, as that is, might be a direction to perſons at a diſtance where to repair home again.

And as there is no good reaſon for thinking that Aſtronomy was cultivated ſo ſoon after the Flood, ſo it is not eaſy to apprehend *what Obſervations* could be made from a tower, of what height ſoever, which they could build, that might not be made as well without.

Though it was ſaid, that Arts and Sciences go no higher than the Flood, yet, it muſt be owned, *Joſephus* places the riſe of Geometry

* Gen. chap. xi.

and Aſtronomy much higher, and aſcribes the invention of them to the ſons of *Seth*, who wrote their diſcoveries on *two pillars*, one of *brick*, and the other of *ſtone*; the laſt of which, he ſays, continued till his time, in the Land of *Siriad*.

Joſephus doth not ſay that he ever ſaw this pillar himſelf; and where this Land of *Siriad* is, no Geographer, or Hiſtorian, has informed us. Mr. *Dodwell* * ſuppoſes it muſt be ſought for in *Egypt*. And it may be that at *Thebes*, or at ſome other place in the *Upper Egypt*, there was a pillar with carvings, ſaid by the Egyptian prieſts to have been the work of of *Thoth*, or *Soth*, which *Joſephus*, for the honour of his nation, was willing to ſuppoſe was the work of their great anceſtor *Seth*, or his immediate deſcendants. And it muſt be farther obſerved, that from the verb *ſaad*, which ſignifies *to aſcend*, the *Upper Egypt* is ſtill called by the Eaſtern Geographers *Said*. It may be then, that *Joſephus*, or the author from whom he tranſcribed this account, wrote χαὶα γῆν ΣΑΙΔΑ, which, being a word not commonly underſtood, was afterwards corrupted into the unmeaning word Σιριάδα.

But to return to the times after the Flood. It muſt be obſerved that there are *three Nations* in particular, who not only boaſt of their great antiquity as nations, but likewiſe of the great antiquity of their *aſtronomical obſervations*: theſe are the *Babylonians*, *Egyptians*, and *Chineſe*. I ſhall only add a word or two here with relation to each of theſe Nations, having ſpoken more at large concerning them upon former occaſions.

THE BABYLONIANS,

ACCORDING to *Tully* †, boaſted of their having obſerved the Heavens for 470,000 years. *Diodorus Siculus* ‡ ſays, 473,000 years; and that from the temple of *Belus*, which was built very high, the *Chaldeans* accurately obſerved the riſings and ſettings of the Stars ‖.

But as he acknowledges that this building was in ruins in his time, and that authors were not agreed in their accounts concerning it, all that he ſays of *it*, and the obſervations made *there*, muſt be looked upon only as hearſay and common report.

Calliſthenes, according to *Porphyry*, as he is cited by *Simplicius* §, ſent *Ariſtotle* from *Babylon*, when it was taken by *Alexander*, obſervations for

* In Append. ad Diſſert. Cyprian. p. 22. † De Divinat. p. 50. ‡ Page 118.
‖ Page 98. § In his Comment on Ariſtotle de Cœlo, p. 123.

1903 years before that time. *Babylon* was taken by *Alexander* about the year before *Chriſt* 330; to this add 1903, and the *Babylonians* will have had obſervations for about 2230 years before *Chriſt*.

But what kind of obſervations theſe were is not known, as no particulars are mentioned, nor any thing more is ſaid of them by any other author than *Simplicius*, who lived under the emperor *Juſtinian*, about the year after *Chriſt* 530.

As to Eclipſes of the Moon, the oldeſt that *Hipparchus* found were of ſervice to him, went no higher than the year before *Chriſt* 721. Whatever obſervations, therefore, the *Chaldeans* had before this, they were probably rude in their kind, and chiefly, if not intirely, related to the *riſings* and *ſettings* of the fixed Stars, and the forming them into Aſſemblages, or Conſtellations.

The *Greeks* are expreſly ſaid by *Herodotus* * to have borrowed the uſe of the Pole and the Gnomon, and the method of dividing the day into twelve parts, from the *Babylonians*. So that by his time they had probably marked the Solſtices and Equinoxes, and conſequently knew, with greater accuracy than formerly, the length of the Tropical Year.

By the beginning of the Chriſtian Æra, it appears, as I have remarked in another place †, they were acquainted with the Moon's *mean motion*, and knew that ſhe had North and South latitude, or did not keep conſtantly in the Ecliptick.

EGYPTIANS.

THE next great pretenders to national antiquity are the *Egyptians*. *Simplicius*, in the place above quoted, ſays, "he had heard that "they had obſervations on the Stars for 2000 years paſt." *Simplicius*, as already has been taken notice of, lived under the emperor *Juſtinian*, about A. D. 530. If therefore he computed from his own time, theſe obſervations began about 1500 years before *Chriſt*. What obſervations theſe were is uncertain; but probably they contained only remarks on the *riſings* and *ſettings* of the fixed Stars with reſpect to the Sun, and the winds, rains, *&c.* attending them. To theſe perhaps might be added the periods of the Moon and Sun, and afterwards thoſe of the other Planets.

* Page 127. † Three Letters to M. Folkes, &c. p. 15.

According

According to *Diogenes Laertius*, the author of their philoſophy was *Nilus*, the father of *Vulcan*. From his time to that of *Alexander the Great* were 48,863 years. But *Dicæarchus*, in the Scholiaſt on *Apollonius* * places *Nilus* only 436 years before the *Olympiads*. Theſe began the year before *Chriſt* 777; therefore *Nilus* lived only 1200 years before *Chriſt*, or about 200 years before the reign of *Solomon*.

From the time of this *Nilus* to *Alexander the Great*, as *Laertius* adds, there had been 373 Eclipſes of the Sun, and 832 of the Moon. But where theſe Eclipſes were obſerved he doth not ſay, nor what authority he had for ſaying they were obſerved at all. It doth not appear that *Hipparchus* made any uſe of Eclipſes obſerved in *Egypt*; becauſe probably neither their times, nor quantities, had been ſet down, at leaſt with ſufficient accuracy, for his purpoſe of ſtating, from them, the *mean motions* of the Sun and Moon.

The *Egyptian* hiſtory is a collection of fable and perplexity. From the reign of the *Sun* to the time of *Alexander the Great* they computed, ſays *Diodorus Siculus* †, about 23000 years. The mention of *Alexander*, plainly ſuggeſts that theſe extravagant computations were made under the *Ptolemies*, by the *Egyptians*, out of envy to the *Greeks*, by whom they were conquered.

Diodorus Siculus ‡ ſays, that he was in *Egypt* himſelf, *Olympiad* 180, about fifty years before *Chriſt*; and that after the Gods and Heroes, who had reigned in that country 18,000 years, they had been governed by Men till that time, during the ſpace of 15,000 years. The whole time, therefore, of the reigns of Gods, Heroes, and Men, amounts to 33,000 years before the beginning of the Chriſtian Æra.

Manetho, as cited by *Diogenes Laertius* §, ſays, that the *Egyptians* taught Σελήνην ἐκλείπειν εἰς τὸ σκίασμα τῆς γῆς ἐμπίπτουσαν, *that the Moon was eclipſed by falling into the Earth's ſhadow*; but how early they were acquainted with this doctrine of eclipſes, is not ſaid.

Diodorus Siculus ‖ ſays, that "obſervations on the order and motions "of the Stars had been made with *particular exactneſs* by the *Egyptians*, "and that they preſerved writings concerning them for an incredible "number of years: that they had obſervations on the *motions*, *periods*, "and *ſtations* of the Planets, and their *influences*: that they could fore-"tel *future events*, as blights, diſeaſes, earthquakes, inundations, and the "*appearance of Comets*."

* Argonaut. p. 186. † Page 22. ‡ Page 41. § Ut ſup. ‖ Page 73.

And

And yet, which is very extraordinary, notwithſtanding the obſervations of the Stars, which the *Egyptians*, he ſays, had wrote down, for *an incredible number of years*, he tells us *, that *Saſuches* " was the in-" ventor of Geometry, and taught them the theory of the Stars, and " the method of obſerving." But *Herodotus*, as we ſhall ſee by-and-by, places the beginning of Geometry no higher than the reign of *Seſoſtris*; and therefore if *Saſuches* be nothing more than the *Seſac* of Scripture, modelled after the *Greek* manner, and *Seſac* the ſame with *Seſoſtris*, as ſome think, the obſervations will go no higher than the time of *Solomon*, or about 1000 years before *Chriſt*.

One thing it will be highly proper to remark in this place, that, among the *Egyptians*, the word *Year* did not always ſtand for the ſame preciſe quantity of time.

In the early ages, according to *Alexander Polyhiſtor* and *Plutarch*, their year conſiſted of *one* month, and afterwards of *four* months, *i. e.* their firſt years were *lunar years*.

Cenſorinus †, but with leſs probability, ſays, that their oldeſt year conſiſted of *two* months; that afterwards it conſiſted of *four* months; and laſtly of *thirteen* months and *five* days. But it is plain this could not be till long after the times we are now ſpeaking of, when they came, by *intercalations*, to adjuſt the motions of the Sun and Moon together.

This laſt obſervation will greatly qualify *the incredible number of years*, as they are called by *Diodorus* above; but to judge of the *exactneſs* of the *Egyptian* obſervations, it could have been wiſhed that he had preſerved an example. It is probable all that he ſays of the *Egyptians* and their obſervations, is nothing more than what he had by word of mouth from the prieſts: for it no where appears from *Diodorus*, or *Herodotus* before him, that the *Egyptians* had any *books*, or that the *Greeks* ever ſaw them, or could read them, if they ſaw them.

'Tis true, indeed, *Clemens Alexandrinus* §, about A.D. 204, an *Egyptian* by birth, and a man of great learning, ſpeaking of ſome *Egyptian* ceremonies, ſays, the prieſts were to learn by heart what was contained in a certain number of *books* wrote by *Mercury*.

But the good father knew nothing of theſe books himſelf, and was greatly impoſed upon. *John Henry Urſinus*, in his *Familiar Exercitations*, and the learned Mr. *Arnold* of *Nuremberg*, will have the books aſcribed to *Hermes* or *Thoth*, to be a forgery of the ſecond century. But it is likely the forgery, at leaſt in part, was older: for among the books attributed to

* Page 84. † De Die Nat. cap. 19. § Stromat. lib. vi. p. 633.

him

him was a treatiſe on Botany, mentioned by *Galen* *, who, at the ſame time condemns it as λῆρος καὶ πλάσμαλα, *an idle forgery*. But *Galen* flouriſhed under *Trajan* and the three ſucceeding emperors, about A. D. 100, and therefore near 100 years before *Clemens Alexandrinus*.

CHINESE.

THE next pretenders to great national antiquity, are the *Chineſe*. Very extraordinary things are told us, by the *Jeſuits*, of their Aſtronomy and Mathematics; but how uncertain, and, in many caſes, how contradictory to all reaſon and truth thoſe accounts are, I have ſhewn at large in the *Philoſophical Tranſactions* †. And what is there ſaid, is confirmed by Mr. *Renaudot*, a learned *Frenchman*, in a Diſſertation at the end of his Tranſlation of ancient Accounts of *China*, by two *Mohammedan* travellers, who went thither in the ninth century.

I ſhall not repeat what I have already ſaid, but only obſerve, that in order to clear up the confuſed accounts given of their Aſtronomy, it may, perhaps, be of ſervice to diſtinguiſh the Hiſtory of it into *three* periods;---the time before the Æra of *Nabonaſſar*;---from thence to the time of *Ptolemy*;---from thence to the coming of the *Jeſuits* into *China*.

Under the firſt of theſe periods, I think, we have nothing more than an Eclipſe of the Sun, ſaid to have been obſerved the year before *Chriſt* 2155, and a Winter Solſtice the year before *Chriſt* 1111, till we come to the year before *Chriſt* 882, when they give us another Solar Eclipſe. *Martini*, indeed, ſpeaks of a Winter Solſtice, obſerved by them 2342 years before *Chriſt*.

The great difficulty here, is to comprehend in what manner ſo *very old* an Eclipſe of the Sun ſhould have been preſerved, and no other, during ſo long an interval of time as 1273 years. May we not ſuſpect that theſe *ſuppoſed obſervations* are in reality nothing more than the reſult of ſome bungling calculation? Mr. *Caſſini*, upon calculating this Solſtice of *Martini*, found an error in it of 500 years; as likewiſe in the conjunction of the five Planets, ſaid to have been obſerved in the *Chineſe* Conſtellation XE ‡.

* De Simp. Medicam. lib. vi. † Vol. xliv. p. 476. ‡ Renaud. p. 211. ut ſup.

As

As to the Eclipſe the year before *Chriſt* 882, that is but juſt before the æra of *Nabonaſſar*, when we know the *Chaldeans* did obſerve, and might be allowed; but the *Chineſe* hiſtory, it ſeems, doth not remark even the *day* on which it happened *. This account, therefore, can be at beſt but barely *hiſtorical*, and ſhews that this Eclipſe could not have been obſerved by them as Aſtronomers; that is, it doth not appear that they knew any uſe to be made of it.

When the *Jeſuits* tell us †, that the *Lamas*, or the prieſts of *Tibet*, have very ancient books of Hiſtory and Aſtronomy, and that they mention the tranſactions at the building of the tower of *Babel*, we may ſafely conclude them, I believe, to be ill-grounded reports, and not too haſtily to be credited. For the *Jeſuits* do not ſay, that they had ſo much as ſeen theſe books, and much leſs peruſed them: and how little haſty or common reports are to be credited, without examination, may be learned from every day's experience.

I have already obſerved ‡, what little dependance can be had on the Chineſe Hiſtory; ſince they ſay themſelves, that their books of Hiſtory, their claſſical books (whatever thoſe mean) and their books of Aſtronomy, were burned, by order of the emperor *Tſin-chi-hoang*, about the year before *Chriſt* 246; their books of Medicine, Aſtrology, and Agriculture, alone being ſpared §.

This Hiſtory, no doubt, is very extraordinary; and if not intirely falſe, yet cannot be fairly repreſented.

Aſtronomy, I am afraid, originally owes its birth and progreſs to Aſtrology; and it ought to be made appear that the Chineſe conſidered and treated the two ſciences as really diſtinct. But when the *Jeſuits* tell us, that they "ſuppoſe a mutual relation between the actions of princes "and ſubjects and the celeſtial phenomena, and that it is in order to "diſcover that relation that their Aſtronomers have employed all their "pains ‖," is it not the ſame thing as, in other words, to declare, that the two ſciences were among them, as every where elſe, confounded, and looked upon as one and the ſame.

The prince, therefore, that burned aſtronomical books, burned likewiſe aſtrological books: and the fact may have been, that the Aſtrologers had either foretold to this prince ſome event of conſequence, that never came to paſs, or ſomething that tended to diſturb the ſtate; and if, on either of theſe ſuppoſitions, he ordered all aſtrological books to

* Obſervat. Math. Aſtron. &c. vol. iii. p. 236. † Vol. ii. p. 120—127.
‡ Philoſ. Tranſact. ut. ſup. § Vol. ii. p. 2. ‖ Vol. ii. p. 31.

be burned, it is not ſo much to be wondered at; and as by this means the ſcience of Aſtronomy, if it muſt be ſo called, was brought into diſrepute, we cannot be ſurprized, that from the time of *Tſin-chi-hoang*, as the *Jeſuits* themſelves obſerve *, "there were among the Chineſe neither "ſkilful Aſtronomers, nor books of Aſtronomy, nor any known me-"thod; and that all that remained were only confuſed traditions, cata-"logues of Stars and Conſtellations, and fragments of books that had "lain concealed."

Having ſaid already ſo much on Obſervations and Obſervers, and as we ſhall have occaſion, all along as we proceed, to ſay more, it will not be improper, in this place, to add ſomething on the nature and

THE USES OF OBSERVATIONS.

Obſervations ſeem at firſt to have been made, and muſt be ſo, both in order and nature, on the fixed Stars.

And thoſe fixed Stars were probably firſt obſerved that lay in or near the way of the Sun and Moon. For obſerving the time between the Sun's leaving any fixed Star till his return to it again, the ancients determined, rudely enough, we may ſuppoſe, at firſt, the

LENGTH OF THE YEAR.

In the ſame manner, by obſerving the time between the Moon's leaving any fixed Star, and returning to it again, they ſtated, we may ſuppoſe, the Moon's

PERIODICAL REVOLUTION.

What hath been here ſaid of the Sun and Moon, will equally hold good with regard to the

PERIODS OF THE PLANETS.

It is only by obſerving the appulſes of the Moon and Planets to fixed Stars, that the

* Vol. ii. p. 3.

INCLINATIONS

INCLINATIONS OF THEIR ORBITS,

and the quantities of thoſe Inclinations, or their greateſt Latitudes, were diſcovered, or aſcertained.

By obſerving the height of the Pole, we diſcover the LATITUDE of the place we live in. And ſince the complement of LATITUDE is equal to the

HEIGHT OF THE EQUATOR,

if we ſubtract that height from the Sun's meridian altitude on the day of the Summer Solſtice, we ſhall have the

OBLIQUITY OF THE ECLIPTIC.

Or, obſerving when the Sun hath the greateſt and leaſt meridian altitudes, and ſubtracting this laſt from the former, it will give the

DISTANCE BETWEEN THE TROPICS.

If this diſtance be divided into two equal parts, it will give the Sun's

GREATEST DECLINATION.

This Declination will be North or South; and if it be added to the Sun's leaſt leaſt meridian altitude, or ſubſtracted from his greateſt, it will give the

HEIGHT OF THE EQUATOR.

And the complement of this to ninety degrees, will give the

HEIGHT OF THE POLE

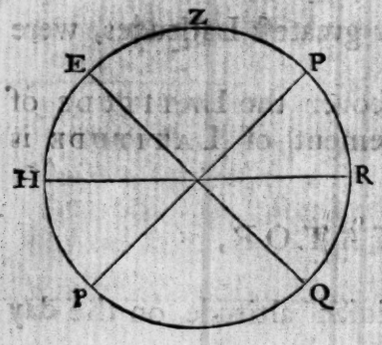
at the place where the Obſervation was made.

Having hitherto conſidered ſuch Circles as are peculiar to the Celeſtial Globe, it will be neceſſary, in the next place, to take a view of ſuch as belong to the Terreſtrial.

On the Terreſtrial Globe are drawn an Equator, Ecliptic, two Tropics, and two Polar Circles, correſponding with thoſe in the Heavens. But this will beſt appear by what is called an

ARMILLARY SPHERE.

DEFINITION.



The Latitude of any place, as Z, is an arch of the Meridian E Z, intercepted between the place Z and the Equator E Q.

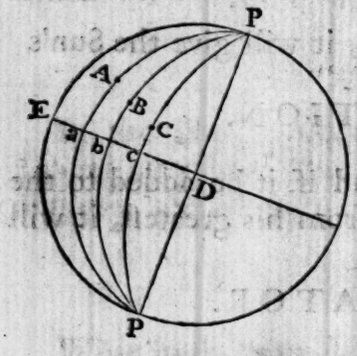
If H R repreſents the Horizon of any place, as Z, then the arch P R will be the height of the Pole there, and the arch H E will be the height of the Equator in that place.

PROPOSITION VI.

The Latitude of any place, E Z, is equal to P R, the height of the Pole there.

For the arch E Z P = 90° = Z P R. From which, if we take the common arch Z P, there remains E Z = P R. W. W. D.

DEFINITION.



The Longitude of any place is an arch of the Equator, intercepted between a Vertical Circle, paſſing through the Poles of the World, P p, and ſome known point in the Equator.

Let D be the known point in the Equator; then the Longitude of the place A will be the arch of the Equator D a, intercepted between the Vertical P A a p and the known point D.

The Circles P A p, P B p, P C p, are called Circles of LATITUDE, or MERIDIANS.

And if the Longitudes of the places A, B, C, are reckoned from one Meridian in particular, as P E p, then ſuch Meridian is commonly called

THE FIRST MERIDIAN.

The poſition of this Firſt Meridian is arbitrary; becauſe on a Sphere, or Globe, there is neither beginning nor end, properly ſpeaking; and therefore any place may be taken indifferently for the beginning, in ſuch kind of reckonings as theſe.

The

The first person, whose works at least are come down to us, who computed the distances of places by Longitudes and Latitudes, was *Ptolemy*, about the year after *Christ* 140.

And the reason why the distances of places, as they lie East and West of each other, were called their Longitude, was, perhaps, becaufe the ancients knew more of the habitable World, from East to West, than from North to South; and therefore they called the first its length, and the other its breadth *

Ptolemy made his FIRST MERIDIAN to pass through what were then called

THE FORTUNATE ISLANDS.

But where these FORTUNATE ISLANDS lay, is uncertain. By some they are supposed to be the same with those now called the CANARIES; and indeed one of *Ptolemy*'s FORTUNATE ISLANDS is called by himself, in his Geography, Καναρία Νῆσος; and to this he assigns Longitude 1° and Latitude 11° North.

In what manner these FORTUNATE ISLANDS might have been discovered, will be seen when we come to speak of Navigation. In the mean time we may form the following

PROBLEM.

To find on the Globe the Longitude and Latitude of any given or known place.

Turn the Globe round its axis, till the given place lies exactly under the (Eastern side of the brass) Meridian, then that degree upon the Meridian which is directly over it, is the Latitude; which is North or South, as it lies in the Northern or Southern Hemisphere.

The Globe remaining in the same position, that degree upon the Equator which is cut by the brass Meridian, is the Longitude required from the first Meridian upon the Globe.

If the Longitude is counted both ways from the first Meridian upon the Globe, then it is to be considered, whether the given place lies easterly or westerly from the first Meridian, and the Longitude must be expressed accordingly.

To this, likewise, we may add the following

* See Varen. Geog. vol. ii. p. 670.

PROBLEM.

PROBLEM.

The Longitude and Latitude being given, to find the place on the Globe.

Seek for the given Longitude in the Equator, and bring that point to the Meridian; then count from the Equator on the Meridian the degree of Latitude given towards the North or South Pole, according as the Latitude is northerly or southerly; and under that degree of Latitude lies the place required.

N. B. It is usual with Sailors to reckon their Longitudes from the last point of Land which they saw at their setting out, as *e. g.* the *Lizard*, the most western promontory of *Cornwall*; and this they call

THE DEPARTURE.

With these last is intimately connected the following

PROBLEM,

To find the difference of Longitude between any two given places.

Bring each of the given places successively to the Meridian, and mark where the Meridian cuts the Equator each time; the number of degrees contained between those two points will be the difference of Longitude required.

Or, having brought one of the given places to the Meridian, bring the index of the Hour Circle to twelve o'clock; then having brought the other place to the Meridian, the number of Hours contained between the place the index was first set at, and the place where it now points is the difference of Longitude in *Time* betwixt the two places.

EXAMPLE,

The difference of Longitude betwixt *Rome* and *Constantinople* will be found to be 19 deg. or 1 hour 15 min. in Time.

Sometimes it will be of use to try the following Problems.

PROBLEM

PROBLEM I.

Any place being given, to find on the Globe all thoſe places that have the ſame Latitude with the given place.

The Latitude of the place being marked upon the Meridian, turn the Globe round its axis, and all thoſe places that paſs under the ſaid mark, are in the ſame Latitude with the given place.

PROBLEM II.

To find the difference of Latitude between two places on the Globe.

This Problem admits of two Caſes.

I. If the places lie both of them on the ſame ſide of the Equator.

II. If the places lie on different ſides of the Equator.

Bring each of the places propoſed ſucceſſively to the Meridian, and obſerve where they interſect it. If the places lie on the ſame ſide of the Equator, ſubſtract the leſſer Latitude from the greater, and the difference will be the difference of Latitude required between the two places.

But if the places lie on different ſides of the Equator, then add the two Latitudes together, and, in this caſe, the ſum will be the difference of Latitude required.

In the poſition of the firſt Meridian, given above, *Ptolemy* is followed by *Al Fraganius* and *Al Batanius*, two learned Arabian Aſtronomers. For it doth not appear that the Arabians had either Geography, or Aſtronomy, before they became acquainted with the writings of *Ptolemy*.

But *Abulfeda*, prince of *Hamah*, a very celebrated Hiſtorian and Geographer, who died an. (Heg. 733.) Chr. 1332, computes his Longitudes from the extreme weſtern promontory of *Africa*, where, as is ſuppoſed, were *Hercules's Pillars*.

This promontory is, again, ſuppoſed to be 10 degrees to the eaſt of the *Fortunate Iſlands*; which is the reaſon why the Longitudes of places in *Abulfeda* are 10 degrees leſs than in the other Arabians that follow *Ptolemy* *.

This obſervation is neceſſary to be remembered, whenever we compare the Longitudes of places in *Abulfeda* with thoſe of other Arabian Geographers that follow *Ptolemy*.

* See Greaves, in Hudſ. Geog. Min. p. 8.

But

But neither of these positions of the first Meridian hath been always followed.

For it was afterwards placed through *Tercera*, one of the Islands called the AZORES.

But this could not be before the year after *Christ* 1448, when they were first discovered by the Portuguese.

The Dutch placed their first Meridian through the Pike of *Teneriff*, because thought to be the highest hill on Earth; and the French, since the year 1634, by command of the French King, have made the Isle of *Ferro*, one of the *Canaries*, their first Meridian *.

Of late years every nation reckons their Longitude from the principal City in their respective Countries, as *London*, *Paris*, *Amsterdam*, &c. The English Astronomers commonly, now, make the Royal Observatory at *Greenwich* their first Meridian, and compute their Longitudes from thence; as the French Astronomers do theirs from the Royal Observatory at *Paris*.

On the Globe the Meridians are drawn through every 15° of Longitude; because 15° on the Equator correspond to 1^h in Time. For

$$360^\circ : 24^h :: 15^\circ : 1^h$$

And so 1° on the Equator will be found to correspond to 4′ of Time.

Upon this principle may be computed such a Table as is here annexed, and will be frequently of great use, as in the following

PROPOSITION VII.

The difference of Time, as reckoned at any two places, being given, to find their difference of Longitude.

EXAMPLE.

Let the Time at *London* be known to be two o'clock in the afternoon; and let the Time observed at another place, suppose *Kamschatscha*, be twelve o'clock at Night; the difference in Time is ten hours. But 10^h by the Table is equal to 150° the difference of Longitude between *London* and *Kamschatscha*.

Kamschatscha is here given as an Example, because of a North-East passage that hath been attempted that way to the *East-Indies*, and because Captain *Behring*, in the Russian service, by means of a lunar

* Varen. Geog. vol. ii. p. 672.

Eclipse,

Eclipſe, obſerved by him there, found that it lies much farther to the Eaſt than it is laid down in our preſent Maps †.

The Ruſſians have ſince publiſhed a Map of Captain *Behring*'s voyage and diſcoveries.

From this difference of Meridians in Time it follows, that if a Ship ſails round the World, ſtill directing her courſe eaſtward, ſhe will, at her return home, find ſhe hath gained one whole day of thoſe that ſtaid at home; that is, if they reckon it *May* 1, the Ship's company will reckon it *May* 2; if weſtward, a day leſs, or *April* 30.

This hath been taken notice of by navigators. "It was during our ſtay "at *Mindanao* (ſays Captain *Dampier*) that we were firſt made ſenſible "of the change of Time in the courſe of our voyage. For having tra- "velled ſo far weſtward, keeping the ſame courſe with the Sun, we con- "ſequently have gained ſomething inſenſibly in the length of the parti- "cular days; but have loſt, in the tale, the bulk or number of the days "or hours."

"According to the different Longitudes of *England* and *Mindanao*, this "Iſle being to the Weſt from the *Lizard*, by common computation, "about 210 degrees, the difference of Time, at our arrival at *Mindanao*, "ought to have been about fourteen hours; and ſo much we ſhould "have anticipated our reckoning, having gained it by bearing the Sun "company."

"Now the natural day, in every particular place, muſt be conſonant "to itſelf; but this going about with, or againſt the Sun's courſe, will, "of neceſſity, make a difference in the calculation of the civil day, be- "tween any two places. Accordingly at *Mindanao*, and all other places "in the *Eaſt-Indies*, we found them reckoning a day before us, both "Natives and Europeans. For the Europeans coming eaſtward, by the "*Cape of Good-Hope*, in a courſe contrary to the Sun and us, where- "ever we met, they were a full day before us in their accounts.

"So among the Indian Mahometans here, their *Friday*, the day of "their ſultan's going to their moſques, was *Thurſday* with us, though it "was *Friday* alſo with thoſe that came eaſtward from *Europe*.

"Yet at the *Ladrone* Iſlands, we found the Spaniards of *Guam* keeping "the ſame computation with ourſelves; the reaſon of which, I take to "be, that they ſettled that colony by a courſe weſtward from *Spain*; "the Spaniards going firſt to *America*, and thence to the *Ladrones* and "*Philippines* ‡."

† See the Philoſ. Tranſ. No. 482, and No. 483. ‡ Dampier's Voyages, vol. i. p. 377.

A TABLE

For converting the PARTS of the EQUINOCTIAL into TIME, and *vice versâ*.

G	H. ′	G	H. ′	G	H. ′
1	0. 4	31	2. 4	70	4.40
2	0. 8	32	2. 8	80	5.20
3	0. 12	33	2. 12	90	6.00
4	0. 16	34	2. 16	100	6.40
5	0. 20	35	2. 20	110	7.20
6	0. 24	36	2. 24	120	8.00
7	0. 28	37	2. 28	130	8.40
8	0. 32	38	2. 32	140	9.20
9	0. 36	39	2. 36	150	10.00
10	0. 40	40	2. 40	160	10.40
11	0. 44	41	2. 44	170	11.20
12	0. 48	42	2. 48	180	12.00
13	0. 52	43	2. 52	190	12.40
14	0. 56	44	2. 56	200	13.20
15	1. 0	45	3. 00	210	14.00
16	1. 4	46	3. 4	220	14.40
17	1. 8	47	3. 8	230	15.20
18	1. 12	48	3. 12	240	16.00
19	1. 16	49	3. 16	250	16.40
20	1. 20	50	3. 20	260	17.20
21	1. 24	51	3. 24	270	18.00
22	1. 28	52	3. 28	280	18.40
23	1. 32	53	3. 32	290	19.20
24	1. 36	54	3. 36	300	20.00
25	1. 40	55	3. 40	310	20.40
26	1. 44	56	3. 44	320	21.20
27	1. 48	57	3. 48	330	22.00
28	1. 52	58	3. 52	340	22.40
29	1. 56	59	3. 56	350	23.20
30	2. 0	60	4.00	360	24.00

The

The Longitudes and Latitudes of places give only their relative diſtances on the Globe; the finding their true diſtances gives the following

PROBLEM.

Any place being given, to find the diſtance of that place from another in a great Circle of the Earth.

I. If they lie under the ſame Meridian, bring both the places up to the Meridian, and mark the number of degrees on the Meridian intercepted between them.

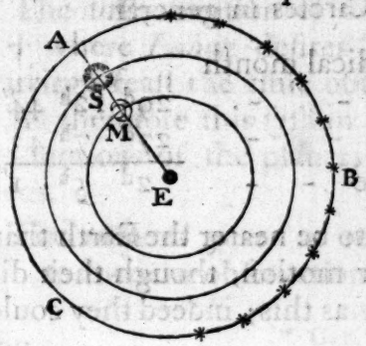
Multiply the number of degrees thus found by ſixty, and they will give the number of Italian, or geographical, miles between the two places. But if we would have the number of Engliſh miles, the degrees before found muſt be multiplied by ſixty-nine and a half, or ſeventy.

II. If the places lie under the Equator, bring them up to the Meridian ſucceſſively, and mark their difference of Longitude in degrees on the Equator; theſe degrees, multiplied by ſeventy, will give the diſtance of the two places from each other in Engliſh miles.

III. If the places lie neither under the ſame Meridian, nor under the Equator, then lay the Quadrant of altitude over the two places, and mark the number of degrees intercepted between them. Theſe degrees, multiplied by ſeventy, will give the number of Engliſh miles between the two places in a great Circle of the Earth.

From the accounts given above of the Egyptians, it ſeems, as already intimated, that the word YEAR was applied firſt to the motion of the Moon.

For the verb שנה *Shanah*, from whence comes the ſubſtantive שנה *a year*, ſignifies *iteravit*, and is applicable to any periodical return. And as that of the Moon is the ſhorteſt, it is probable, the firſt obſervations were made upon her, and afterwards upon the Sun. The oldeſt ſyſtem, therefore, was moſt probably this; the ſimpleſt that can well be imagined.



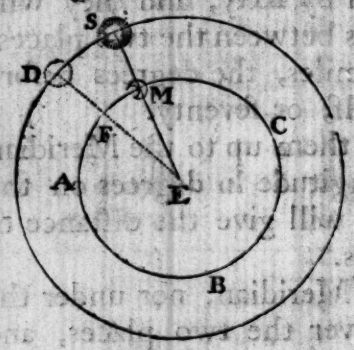
Here ABC is a great Circle in the Heavens, where the fixed Stars and Planets (at firſt not diſtinguiſhed from them) were ſuppoſed to be placed. E the Earth in the center of that Circle; S the Sun, deſcribing a Circle about the Earth in a year; and M the Moon, deſcribing a leſſer Circle about the Earth in a month.

Μήν, the Greek Name for the Moon, ſeems to come from the Hebrew or Chaldee מנה *Manah*,

nah, numeravit, supputavit; and from ירח *Yarah*, or, in the Arabic language, يرح *Arab, præscripto tempore notavit, &c.* comes ירח *Yarah*, another name for the Moon, and likewise for a month; which seems to intimate, as if the oldest measure of time, taken from the revolution of the heavenly bodies, was a month.

The month is of two sorts, PERIODICAL and SYNODICAL. The *first* of these is the time in which the Moon finishes her course in her own orbit about the Earth, without any regard to the Sun. The *second* is all that space of time between one conjunction of the Moon with the Sun, and the next.

This month, perhaps, was originally the *synodical* month only, or, as was just said, the time spent between one conjunction and the next; *i. e.* supposing the Earth at rest at E, the time from the Moon's (☽) leaving the Sun (☉) in describing the Circle A B C, till she came up with him again.



This time, if the Sun stood still likewise, would be always the same; and the PERIODICAL month, and the SYNODICAL month, would be equal, or of the same length.

But while the Moon describes her orbit A B C about the Earth at E, let the Sun, by his apparent annual motion, advance forward from S to D. It is plain that the Moon will not come up in conjunction with the Sun again till, besides describing her orbit, she hath described, over and above, the arch M F, corresponding to the arch S D.

The month, at first, was supposed to be finished in thirty days; and afterwards, when the motion of the Moon came to be compared with, and adjusted to the motion of the Sun, twelve of these were thought to correspond exactly with the Sun's annual course. And therefore, since $30 \times 12 = 360$, this, probably, became the reason why 360 degrees, or parts, were made the common measure of all Circles in general.

But, according to later observations, the synodical month consists of - - - - - -			$29^d\ 12^h\ 44'$
And the periodical month of - - - - -			$27^d\ 7^h\ 43'$
	Difference - -		$2^d\ 5^h\ 1'$

The reason why the Moon was easily supposed to be nearer the Earth than the Sun, was on account of the swiftness of her motion, though their distances were hardly begun to be measured so early as this; indeed they could not

not before Geometry was taught, and applied to the Heavens. But this was not till long enough after the times we are now ſpeaking of.

As we have ſeen that the month is of *two ſorts*, ſo it may not be improper, in the next place, to obſerve, that the year is ſo too.

The time meaſured by the Sun's revolution from any fixed Star to the ſame fixed Star again, contains - $365^d\ 6^h\ 9'\ 14''\ 30'''$ and is called

THE SIDEREAL YEAR.

But the time, meaſured by the Sun's revolution in the Ecliptic, from any Equinox, or Solſtice, to the ſame again, conſiſts now of - - - $365^d\ 5^h\ 48'\ 57''\ 00'''$ and is called

THE TROPICAL YEAR.

The difference between theſe two ſorts of years is - - $20'\ 17''\ 30'''$

And here, in order to underſtand ſome paſſages of Scripture, we may take notice, that what is now called a *year*, ſeems in very early times to have been termed ימים *Yamim*, days, *i. e. a ſyſtem of days*. For when *Rebecca* * ſent her ſon *Jacob* to *Padan-Aram*, to avoid his brother *Eſau*'s reſentment, ſhe adviſeth him to ſtay there ימים אחדים *Yamim ehadim*; our tranſlation ſays, *a few days*. But that is not a tranſlation of the words; for אחד *ehad*, and, in the plural number, אחדים *ehadim*, never ſignifies *a few*. It is properly *dies unos*, i. e. *one ſyſtem of days*, or *a year*. Beſides, the abſence of a *few days* would not have been conſiſtent with ſo long a journey, nor the occaſion of it.

This mode of expreſſion was afterwards laid aſide in common uſe, and was retained, or ſomething like it, only in the prophetic ſtile.

The firſt mention of a ſyſtem of days, called *a week*, or *ſeven days*, is † where *Laban* deſires *Jacob* to fulfil *Leah*'s week, *i. e.* to keep the marriage-feaſt the time out, which was *ſeven* days.

As therefore this ſyſtem was earlier than we have any reaſon to think the motions of the planets were known, it could hardly be derived from them.

The *tropical* year, as remarked above, according to modern obſervations, conſiſts of - - $365^d\ 5^h\ 48'\ 57''$.

* Gen. xxvii. † Gen. xxix. 27.

But

But the time meaſured by twelve revolutions of the Moon, from the Sun to the Sun again, or twelve *ſynodical* months, is found to conſiſt of - $354^d\ 8^h\ 48'\ 37''$

and this is called

THE LUNAR YEAR.

The difference between this and the *tropical* year above, is - - - - - $10^d\ 21^h\ 00'\ 20''$

Within the period we are now ſpeaking of, it ſeems as if ſome obſervations had been made on the fixed Stars, *i. e.* that the appearing of ſuch and ſuch particular Stars in the evening, in the Eaſt, when the Sun was ſetting in the Weſt, called their *achronychal riſing*, or their ſetting along with the Sun in the Weſt, called their *achronychal ſetting*, *&c.* were the cauſes of wind, rain, and other changes, or affections, of the atmoſphere.

The firſt inſtance of this kind, that occurs in any author, ſeems to be †, where the river *Kiſhon* is ſaid to have *ſwept* away the dead bodies of *Siſera*'s army, and that *the Stars in their courſes* fought againſt him.

Kiſhon is an inconſiderable brook; but ſwells by rains that fall from the neighbouring hills, and overflows the Plain of *Eſdraelon*, through which it runs ‡.

At the time, therefore, of *Siſera*'s defeat, it ſeems as if great rains had *fell*, and ſwelled this rivulet, and which is here attributed to the influence of the Stars. This interpretation, at leaſt, ſeems better than the making it only an unmeaning flight of Eaſtern poetry.

There are many inſtances of ſuch ſudden land-floods in the eaſtern parts of the World. The following is a remarkable one.

The author of a journey from *Aleppo* to *Tadmor* in the year 1691, ſays, that being in great diſtreſs for water, they reſolved to ſend their guide, with a ſervant or two, to ſearch for ſome, and afterwards others, with their horſes, while, in the mean time, they pitched their tents, it being then about two o'clock in the afternoon. "As ſoon as they were gone, "(ſays he) a ſmall drizzling rain, which we had about half an hour, "increaſed to a very plentiful ſhower, which put us upon producing all "the veſſels we had to catch it, as it fell from the Heavens, or ran "down the ſkirts of our tents; our horſes at the ſame time greedily "drinking it from the ground. But we might have ſpared our pains; "for in leſs than half an hour's time, our camp was, in a manner, a-float,

† Judg. v. ‡ Maund. Trav. p. 57.

"and

" and we were ſurrounded with water, not only ſufficient for us, but for " an army of 20,000 men; thoſe hollow guts which we paſſed over, " without the leaſt appearance of moiſture, were, by the *cataracts* which " deſcended from the mountains, become rivers; and our guide, with " thoſe ſervants we had ſent out, that before rode over it dry, it being " ſwollen to ſuch a torrent, were put to ſome difficulty to repaſs it; ſo " plentifully was God pleaſed to provide for us in our greateſt ſtreight: " and, which increaſeth both the wonder and mercy, the next morning " all this great quantity of water was paſſed away, ſo that, in about two " hours riding, we could hardly perceive that there had been any rain at " all. This memorable place is known by the name of *Al-wiſhal* *."

From this time, for a long while after, we meet with nothing that looks like obſervations of any ſort. In the Scripture hiſtory, which is of a different kind, it is not to be expected; and the hiſtories of ſuch nations as made any figure in thoſe days, are loſt, or never were wrote.

At laſt, however, under the reign of *Hezekiah*, or about the year before Chriſt 720, we hear, for the firſt time, of the Babylonians, as curious about what paſſed in the Heavens: for they ſent to *Hezekiah* †, to enquire concerning the *ſhadow's going back* on the dial of *Ahaz*.

In what manner, and under what circumſtances, the ſhadow may *go back* on a *ſun-dial*, without a miracle, will be ſeen hereafter. It may be ſufficient to obſerve, at preſent, that it is plain, however this phenomenon muſt be ſolved, it was not cauſed by any real ſtoppage of the Sun's *apparent* diurnal motion; for then it would have been *univerſal*, and perceived at *Babylon*, as well as at *Jeruſalem*. The Babylonians, therefore, had only heard of it; and this appears farther from hence, that it is called the *wonder done in the Land*, *i. e.* the Land of *Judah*.

How early obſervations were made on the fixed Stars, for the purpoſes of travelling, is uncertain. But that they were uſed firſt at land, ſeems reaſonable enough to believe; for we can hardly imagine that men would venture themſelves upon the ſea by night, before they had learned ſome method whereby to direct their courſe.

Diodorus Siculus ‡ ſays, Τὰ δὲ πρὸς δύσμας μέρη κεκλιμένα τῆς Ἀραβιάς, διείληπται πεδίοις ἀμμώδεσιν, ἀερίοις τὸ μέγεθος, δι' ὧν οἱ τὰς ὁδοιπορίας ποιύμενοι, καθάπερ οἱ ἐν τοῖς πελάγεσι, πρὸς τὰς, ἀπὸ τῶν Ἄρκτων, Σημασίας, τὴν διέξοδον ποιοῦνται. " The ſouthern parts of Arabia are made up of ſandy plains " of a prodigious extent; the travellers through which direct their courſe " by *the Bears*, in the ſame manner as is done at ſea."

* See Miſcel. Curioſ. vol. iii. p. 139. † 2 Chron. xxxii. 31. ‡ Page 136.

Diodorus

Diodorus ſeems to have tranſcribed this account from *Agatharchides*; and therefore, we may reaſonably enough conclude, he ſpeaks of a cuſtom practiſed as old as the time of *Alexander the Great*. How long before that it had obtained, is very uncertain.

That people travelled in the vaſt deſerts of Arabia at night by obſerving the Stars, long after this, is directly proved by this paſſage of the *Korân* †, وهو الذي جعل لكم النجوم لتهتدوا بها في ظلمات البر والبحر "*He* "*(i. e.* God) *hath given you the Stars to be your guides in the dark both by* "*land and ſea.*"

This paſſage is a confirmation of the truth of what *Diodorus Siculus* had obſerved before. The practice of thus travelling by land, by the direction of the Stars, may, with great probability, be looked on as very ancient. The cuſtoms and manners of thoſe people, in other inſtances, it is well known, are the ſame with thoſe we read of as prevailing amongſt them in times of remoteſt antiquity.

When men began firſt to ſail by the Stars, or who were the firſt people that did ſo, is not clear. They might probably be the Phœnicians, who ſeem, by their very name, to have been a colony of the Edomites, a people bordering on the Red Sea; and as this Sea lies from North to South, it would afford very proper opportunities of obſerving the *depreſſion* of Stars to the neighbourhood of one Pole, and the *aſcenſion* of other Stars adjoining to the other Pole; and it is to the ſkill of theſe people in navigation, perhaps, that the prophet *Obadiah* * alludes.

The practice of ſailing by the Stars, according to *Homer*, was in uſe among the Greeks as early as the time of the Trojan war. For he ſays of *Ulyſſes*, when ſailing on his raft, that

------ οὐδέ οἱ ὕπνος ἐπὶ βλεφάροισιν ἔπιπτε,
Πληϊάδας τ' ἐσορῶντι καὶ ὀψὲ δύοντα Βοώτην,
Ἄρκτον θ' ἣν καὶ Ἅμαξαν ἐπίκλησιν καλέουσιν,
Ἣ τ' αὐτοῦ στρέφεται καὶ τ' Ὠρίωνα δοκεύει·
Οἴη δ' ἄμμορος ἔστι λοετρῶν Ὠκεανοῖο §.

Placed at the helm he ſate, and mark'd the ſkies,
Nor clos'd in ſleep his ever-watchful eyes.
There view'd the *Pleiads*, and the *Northern Team*,
And great *Orion*'s more refulgent beam;
To which, around the axle of the ſky
The *Bear* revolving, points his golden eye,
Who ſhines exalted on th' ethereal plain,
Nor bathes his blazing forehead in the main.

† Sur. vi. ver. 98. * Ver 8. § Odyſſ. E. ver. 271.

The

The quotation of this paſſage from *Homer*, naturally gives occaſion here to ſay ſomething on the antiquity of forming thoſe aſſemblages of the fixed Stars, called

CONSTELLATIONS.

The Sphere of the Greeks, in many inſtances at leaſt, appears manifeſtly borrowed from other people, particularly the Phœnicians. But the figures received from them, which probably were very ſimple in their kind, and taken from things in moſt common uſe, were ſo metamorphoſed, according to the fanciful genius of that people, as to be no longer viſible under their original forms.

The Egyptians, we are expreſly told by *Achilles Tatius* †, had other figures in their Sphere, very different from thoſe of the Greeks. And it appears, in ſome meaſure, from an Egyptian calendar, preſerved in *Montfaucon* ‡.

Not to mention the Zodiac of the Indians and Chineſe, which differ from each other, as well as from the former, it may not be amiſs juſt to obſerve, that in Scripture, particularly the the book of *Job*, and the prophets *Amos* and *Iſaiah*, we meet with Conſtellations, that ſeem borrowed from the Chaldeans, or Syrians, and are older than any Conſtellations to be met with among the Greeks; ſuch are,

כסילים *Cheſilim*, mentioned *Iſaiah* xiii. 10. And as that chapter contains a prophecy againſt Babylon, it is not unlikely that the Conſtellation itſelf is Babylonian: and as the word is plural, it ſeems, for reaſons too long to enlarge on here, to mean the Conſtellations now called the *Great* and *Little Bear*.

Whether the Greeks borrowed the Conſtellation called the *Great Bear* from ſome other people, or formed it themſelves, is uncertain. But hearing that Conſtellation called by ſome other people חלשתא *Chaliſto*, a word of much the ſame import with *Cheſil*, and knowing that *Lycaon* had a daughter called *Caliſto*, they took occaſion to coin the fancy that ſhe was turned into the Conſtellation called the *Bear*.

כימה *Chimah*, mentioned both in *Amos* and the book of *Job*, is nothing more than an *armed man*, and therefore naturally directs us to the Conſtellation *Orion*, a very old one among the Greeks, as

† In Petav. Uranolog. p. 164. ‡ Supplement to his Antiq. Expliq.

was ſeen above from *Homer*, and beautifully deſcribed by *Germanicus* under the ſame image.

At contra nullo defectus lumine, totus
Orion *humeris ſplendebit, magnaq; divi*
Vagina, & claro cælatus Balteus igni.

עיש *Aiſh*, mentioned twice in the book of *Job*, ſignifies nothing more than a *Cluſter*; and therefore ſeems to be the ſame Conſtellation with the *Pleiades* of the Greeks. And as it is deſcribed *along with its ſons*, theſe may mean the reſt of the Stars attending or following them; for the year began, in thoſe early times, with the *heliacal riſings* of the *Pleiades*.

נחש בריח *Nahaſh-barih*, or the *Long Serpent*, in the book of *Job*, ſeems to denote ſome Conſtellation or other; but whether the Conſtellation *Draco* be intended, is hard to ſay. It is certain, however, that obſervations were made upon this by the ancients, for the purpoſes of *huſbandry*, as well as of *ſailing*, as appears from *Virgil*.

Hædorumq; dies ſervandi & lucidus anguis.

מזרות *Mazaroth*, ſeems to have been a *broad Circle*, comprehending all ſuch Stars as lie in the way of the Sun and Moon. And as different parts of this Circle riſe *heliacally* at different ſeaſons of the year, we may eaſily comprehend what is meant * by "*bringing forth* Mazaroth *in its ſeaſon*."

מזלות *Mazaloth*, mentioned 2 *Kings* xxiii. 5. may very probably be the *Menâzil al kamer* of the Arabians, or the *Manſions of the Moon* already ſpoken of.

חדרי תימן *Hadri-teiman*, the *Private Chambers of the South* †, ſeem to mean no Conſtellations in particular, but to comprehend all the Stars lying towards the South Pole, and inviſible in the Latitude of Babylon, or wherever the book of *Job* was compoſed.

The Conſtellations hitherto mentioned, were, perhaps, only in the Sphere of the Chaldeans.

Whether the Egyptians, or any other people, at this time had a Sphere of their own, different from this, or wherein that difference conſiſted, is uncertain.

* Job. xxxviii. 32. † Job. ix.

The

The Sphere of the Indians is very different from that of the Greeks, according to the *Jeſuits* ‡, and conſiſts of figures very ſimple in their kind, as an Elephant's head and trunk, the goad to prick him with, an Umbrella, a Fiſhing-Net, a Trumpet, Rubies, Precious Stones, Triangles, *&c.*

The Zodiac of the Indians conſiſts of twenty-ſeven Conſtellations; each Conſtellation is divided into four parts, and every part denoted by a particular monoſyllable. Their order, *&c.* is as follows §.

ACHEVINI	1. Tchou. Tche. Tcho. La.	
BARANI	2. Li. Lou. Le. Lo.	
CRITICA *	3. A. Io. Ou. I.	* This anſwers, it ſeems, to the Pleiades.
ROHINI	4. Ge. Va. Vi. Vou.	
MROUGACHIRA	5. I. Vo. Ka. Ki.	
ARIDRA	6. Kou. Gam. Ga. Tcha.	† This anſwers to the bright Stars in the heads of Caſtor and Pollux, together with Procyon.
POUVARNASSOU	7. Ke. Ko. Ha. Hi.	
POUCHIAMI	8. Ou. He. Ho. Da.	
ACHLECHA †	9. Di. Dou. De. Do.	
MAGGA ‡	10. Ma. Mi. Mou. Me.	‡ This anſwers to the Lion's mane and heart.
POUBBA	11. Mo. Ta. Ti. Tou.	
OUTTERA	12. Te. To. Pa. Pi.	
HASTA	13. Pau. Chan. Na. Da.	
CITA	14. Pe. Po. Ra. Ri.	
SUATI	15. Rou. Re. Ro. Ra.	
VICHACA §	16. Ti. Tou. Te. To.	§ Anſwers to the Northern Crown.
ANORADA ‖	17. Na. Ni. Nou. Ne.	‖ This anſwers to Scorpio and part of Serpentarius.
JEOSTA	18. No. Ja. J. Jou.	
MOULA	19. Je. Jo. Ba. Bi.	
POURVACHADA	20. Bou. Da. Ba. Da.	
OUTTERACHADA	21. Be. Bo. Ja. Gi.	
CHRAVENA	22. Ki. Kou. Ke. Ko.	
DANICHTA *	23. Ga. Gui. Gou. Gue.	* This includes the Stars compoſing the Dolphin.
CATABITCHA	24. Gc. Sa. Si. Sou.	
POURVABADRA	25. Se. So. Da. Di.	
OUTTERABADRA	26. Dou. Chan. Wa. Ta.	
REVETI	27. De. Do. Cha. Chi.	

‡ Obſervat. tom. i. p. 247. § Obſerv. &c. vol. i. p. 243.

The Zodiac of the Chineſe conſiſts of the following animals, and in the following order, 1. A Mouſe. 2. An Ox. 3. A Tyger. 4. A Hare. 5. A Crocodile. 6. A Serpent. 7. A Horſe. 8. A Ram. 9. A Monkey. 10. A Hen. 11. A Dog. 12. A Hog.

Theſe may be ſeen on a coin of Count *Oſterman*, in *Bayer's Horæ Sinicæ* *. But what antiquity they are of, is uncertain.

Obſervations on the fixed Stars, it muſt be remarked, are the foundation of all Aſtronomy. For by them alone can be determined the length of the ſolar year, the lunar month, and the periods of the Planets.

OBSERVATION.

The Sphere of the Greeks ſeems to have been compoſed from thoſe of the Chaldeans, Phœnicians, and Egyptians, at different times, and by degrees, but new modelled by them, and accommodated to their *fabulous hiſtory*. Or what, perhaps, may be, in ſeveral inſtances at leaſt, really the caſe, their *fabulous hiſtory* is nothing more than a corruption of exotic names of the Conſtellations.

Thus, *e. g. Andromeda* may be nothing more in the old original Phœnician Sphere than *a wide threſhing-floor*, and *Caſſiopeia*, or *mulier tecta facie*, the *Courtezan*; ſuch women attending upon *harveſt-homes*, and the like feſtivals, but in veils when deſigned for proſtitution, as may be gathered from *Geneſis* †. *Cepheus*, though by the Greeks dignified with the title of king of Ethiopia, and made the father of *Andromeda*, yet ſignifies nothing more than *qui pone ſequitur*, becauſe following the *leſſer Bear*, as *Arctophylax* doth the *greater*. But the proof of all this belongs to

MYTHOLOGY.

As the fixed Stars, ſuppoſed, as was obſerved before, to be the cauſes of the different affections of the Atmoſphere, and therefore the aſſemblages of them, or the Conſtellations, riſe and ſet at different hours at different times of the year, which depends on the Sun's motion, before we can ſolve anyProblem relating to them, we muſt ſolve the following

PROBLEM.

The day of the month being given, to find the Sun's place in the Ecliptic, his declination, and right aſcenſion.

* Page 16. † Chap. xxxviii. ver. 15.

Look

Look for the given day of the Month on the wooden Horizon, and oppoſite to it will be found the Sun's place in the Ecliptic.

Bring the Sun's place, ſo found, to the braſs Meridian, the point of the Equator then under it will ſhew the Sun's right aſcenſion; and the arch of the Meridian intercepted between the Equator and the Sun's place, will ſhew his declination.

As the Sun, Moon, and Stars do not riſe and ſet to all places alike, before we can ſolve any Problem relating to them for any *one* particular place upon Earth, we muſt firſt ſolve the following

PROBLEM.

To rectify the Globe for the Latitude of the place, the Zenith, and the Sun's place.

I. If the place be in the Northern Hemiſphere, raiſe the North Pole above the Horizon; but if the place be in the Southern Hemiſphere, raiſe the South Pole. Then move the Meridian up and down in the notches, till the degree of the place's Latitude, counted upon the Meridian, below the Pole, cuts the Horizon; and then the Globe is adjuſted to the Latitude of the place.

II. Having elevated the Globe according to the Latitude of the place, count the ſame number of degrees upon the Meridian, from the Equator towards the elevated Pole, and that point will be the Zenith or Vertex of the place. To this point of the Meridian ſcrew the Quadrant of Altitude, ſo that its graduated edge may be joined to the ſaid point; then is the Globe rectified for the Zenith.

III. Bring the Sun's place in the Ecliptic to the Meridian, and ſet the hour-index to twelve at noon; and then the Globe will be rectified for the Sun's place.

Since the declination of the Sun, and the time of the day, at any particular place on the Earth, are continually changing, we may add the two following Problems, which will be found of uſe hereafter.

PROBLEM I.

The day of the month being given, to find all thoſe places on the Globe to which the Sun will be vertical that day.

Oppoſite to the day of the month, on the wooden Horizon, will be found the Sun's place in the Ecliptic. Bring the Sun's place, ſo found, to the braſs Meridian, and mark on it the Sun's declination; then turn the

the Globe about its axis, and all thoſe places that come under that mark, will have the Sun vertical to them on that day.

REMARK.

When the hour is ſaid to be given, it is always underſtood to be the hour at ſome particular place, as *London*, *Paris*, *&c.* This is neceſſary to be taken notice of, for the ſake of the following

PROBLEM.

The day of the month and the hour being given, to find that place upon the Globe to which the Sun will be then vertical.

Having found the Sun's declination, as before, bring the place for which the hour is given to the braſs Meridian, and ſet the hour-index to the given hour. Then turn the Globe about its axis till the hour-index points to twelve at noon; then that place upon the Globe which ſtands under the point of the Sun's declination, marked upon the braſs Meridian, will have the Sun that moment in its vertex.

In comparing together the obſervations of the ancients, it appears, that they confounded together obſervations on the riſings and ſettings of the Stars, made in very diſtant countries or Latitudes. In order to avoid the like error, it will be proper to attend to the following

DEFINITION.

An arch of the Horizon, intercepted between the the true Eaſt or Weſt points of it, and that point upon which the Sun, or any Star, riſes or ſets, is called the Sun's or Star's

AMPLITUDE.

From whence we have the following

PROBLEM.

The Latitude of the place, and the place of the Sun being given, to find his AMPLITUDE by the Globe.

Rectify the Globe for the Latitude of the place, and bring the Sun's place to the eaſtern ſide of the Horizon, the arch of the Horizon intercepted

cepted between that point and the eaſtern point, will be the Sun's Amplitude at riſing.

If the ſame point be brought to the weſtern ſide of the Horizon, the arch of the Horizon intercepted between that point and the weſtern point, will be the Sun's Amplitude at ſetting.

N. B. This Amplitude of the Sun at riſing and ſetting, increaſes with the Latitude of the place; and in very high northern latitudes, the Sun ſcarce ſets before he riſes again. *Homer* had heard ſomething of this, though it cannot be true of the *Læſtrygones*, to whom he applies it.

——— Ὅθι ποιμένα ποιμὴν
Ηπύει ἐισελάων ὅδε δ' ἐξελάων ὑπακούει.
Ενθα κ' ἄϋπνος ἀνὴρ δοιὼς ἐξήρατο μισθὸς
Τὸν μὲν βουκολέων, τὸν δ' ἀργυφα μῆλα νομεύων·
Εγγὺς γὰρ νυκτὸς τε καὶ ἤματος εἰσι κέλευθοι. *

Six days and nights a doubtful courſe we ſteer;
The next, proud *Latmos'* lofty towers appear,
And *Leſtrygonia*'s gates ariſe diſtinct in air.
The ſhepherd quitting here at night the plain,
Calls to ſucceed his cares the watchful ſwain.
But he that ſcorns the chains of ſleep to wear,
And adds the herdſman's to the ſhepherd's care,
So near the paſtures, and ſo ſhort the way,
His double toils may claim a double pay,
And join the labours of the night and day.

The Tranſlator miſtakes the laſt line in *Homer*; but the Scholiaſt on *Aratus* † underſtood it as I do.

As the hour of the day at any place depends upon the Sun's apparent diurnal motion; and as the Sun's height above the Horizon, from the time of his riſing till noon, and from thence till the time of his ſetting, is continually changing; and as his diſtance from the Meridian, meaſured in an arch of the Horizon, is continually doing the ſame; and as both theſe depend on the Latitude of the place, and the time of the year, or the Sun's place in the Ecliptic, we have, therefore, the following Problems.

* Odyſſ. K. ver. 82. † Page 12. Edit. Oxon.

PROBLEM.

PROBLEM.

The latitude of the place, the Sun's place, and his Altitude, being given, it is required to find the hour of the day, and the Sun's Azimuth from the Meridian.

Having rectified the Globe for the latitude, the zenith, and the Sun's place, turn the Globe and the Quadrant of Altitude, ſo that the Sun's place may cut the given degree of Altitude; then the hour-index will ſhew the hour; and the point where the Quadrant of altitude cuts the Horizon, will ſhew the Azimuth.

OBSERVATION.

In this Problem are contained five things, *viz.* the latitude of the place, the Sun's place, his Altitude, his Azimuth, and the hour of the day.

Of theſe five things the three firſt are given, in order to find the two laſt; and in the ſame manner, any three of theſe five being given, we may find the remaining two.

PROBLEM.

The latitude of the place, the hour of the day, and the Sun's place, being given, to find the Sun's Altitude and Azimuth by the Globe.

Rectify the Globe for the latitude of the place, the zenith, and the Sun's place; then the number of degrees contained between the Sun's place and the Vertex, is the diſtance of the Sun from the Vertex at noon; and the complement of this to ninety degrees is the Sun's meridian Altitude.

If you turn the Globe about its axis till the hour-index points to any other given hour, then bring the Quadrant of altitude to cut the Sun's place, and you will have the Sun's altitude at that hour; and where the Quadrant cuts the Horizon, is the Sun's azimuth at the ſame time.

PROBLEM.

The latitude of the place, the Sun's place, and his Azimuth, being given, to find his Altitude, and the hour.

Rectify the Globe for the latitude, the zenith, and the Sun's place; then put the Quadrant of Altitude to the Sun's Azimuth in the Horizon, and turn the Globe till the Sun's place meet the edge of the Quadrant; then

then the ſaid edge will ſhew the altitude, and the hour-index will point to the hour.

PROBLEM.

The Latitude of the place, the Sun's altitude and his azimuth, being given, to find his place in the Ecliptick, and the hour.

Rectify the Globe for the Latitude and Zenith of the place, and ſet the edge of the Quadrant to the given azimuth; then turning the Globe about, that point of the Ecliptick which cuts the altitude, will be the Sun's place. Keep the Quadrant of altitude in the ſame poſition, and having brought the Sun's place to the Meridian, and the hour-index to twelve at noon, turn the Globe about till the Sun's place cuts the Quadrant of altitude, and then the hour-index will point to the hour of the day.

Having ſpoken of the fixed Stars, and the Aſſemblages of them, or Conſtellations, and the practice of obſerving them for the purpoſes of Navigation, it will not be intirely foreign to the ſubject, if we trace a little the hiſtory of

NAVIGATION.

The oldeſt hiſtory extant is that of the Old Teſtament; and the firſt mention that we there find of ſhips is *Gen.* xlix. 13. where it is ſaid, that "*Zebulon ſhall dwell at the haven of the ſea, and he ſhall be for an haven of ſhips.*"

This, in the margin of our Bibles, is placed about the year before *Chriſt* 1689.

We find ſhipping mentioned again in other places *. But there is no account of long voyages undertaken before the time of *Solomon*, or about the year before *Chriſt* 1000.

We are then told, "that he made a navy of ſhips in *Ezion-Geber*, "which is beſide *Eloth*, on the ſhore of the *Red Sea*, in the Land of "*Edom* †." How long, before this, navigation had been practiſed by the Phœnicians, or Edomites, doth not appear. That the Jews, however, were but little acquainted with it, may be gathered from the next verſe, where it is ſaid, that "*Hiram* (king of *Tyre*) ſent in the navy his ſervants, ſhipmen that had knowledge of the ſea, with the ſervants of "*Solomon.*"

* Deut. xxviii. 68.—Judg. v. 17. † 1 King. ix. 25.

According to the heathen writers, the first ſailors were the *Tyrians*; or, perhaps, they meant that the *Tyrians* were the first that fitted ſhips with *maſts* and *ſails*. Thus *Tibullus* ſeems to have underſtood it *.

Prima ratem ventis credere docta Tyros.

Perhaps the word *Tyros*, here, is not to be confined to the city of *Tyre*, but may comprehend the territory belonging to it. And then it may be remarked, by the way, that we not only find on the coins of *Tyre* a *triremis*, but on thoſe of *Byblus*, a maritime city of *Phœnicia*, a woman (ſuppoſed by ſome to be *Iſis*) holding in her hands a ſail †.

Iſis is a fictitious being, and frequently means nothing more than the Moon, the mythological wife of the Sun. When particular inventions, then, are aſcribed to her, the meaning ſeems to be, either that they were diſcovered during the time that the Egyptians made uſe of *lunar years*, or were ſo old that it could not be known when, or by whom, they were diſcovered.

That *Solomon*'s navy ſailed down the Red Sea, or the Arabian Gulph, is evident from the place where the ſhips were built; but where they went, is not ſo certain. The text ſays only ‡, that "they came to *Ophir*, and "fetched from thence *gold*;" and it is added §, "*ſilver*, *ivory*, *apes*, "and *peacocks*, *almug-trees*, and *precious ſtones*."

The Greek verſion of 1 *Kings* ix. calls the place Σωφρά, or, as in the Alexandrian Copy, Σωφαρά. The Syriac Verſion, and the Chaldee Paraphraſt, retain the word *Ophir*; but the Arabic Verſion ſays, نخرجوا الي بلاد دهلك التي من الهند *egreſſi ſunt ad regiones* Dahlak, *quæ ſunt in* India. But the authority of this Verſion is not very great.

The learned *Hadrian Reland* hath a diſſertation on this place *Ophir*, where he ſays, that whatever is affirmed in Scripture, concerning this place, agrees very well with the country where was the city *Oupara*, or *Soupara*, or, as it is called likewiſe, *Ophir* and *Sophir*. It is a city mentioned by *Ptolemy*, *Ammianus Marcellinus*, and *Arrian*.

It lies on the Indian Cherſoneſus, within Ganges, between 112° and 113° of Longitude Eaſt, and about 15° Latitude South.

Bochart thinks ¶, that this *Ophir* was the iſland *Taprobana* of the ancients, or *Ceylon*, as it is now called. For this Iſland affords gold, ivory, precious ſtones, and peacocks, and the neighbouring Cherſoneſus monkeys.

* L. i. Eleg. vii. ver. 20. † Noris de epoch. Syromaced. p. 394—468. ‡ Ver. 28.
§ Chap. x. ver. 11.——22. ¶ In his Phaleg. l. ii. c. 17.

That

That the place was diſcovered by the Phœnicians, ſeems not improbable from hence, that *Solomon*, as was obſerved, employed Phœnician ſailors to go along with his own people; and *Jambulus*, the name of the diſcoverer in *Diodorus Siculus* *, is plainly Phœnician, however fictitious all the reſt of the ſtory ſeems to be.

Joſephus † ſpeaks very obſcurely about *Ophir*, and ſeems, contrary to all probability, to place it the other way, towards the Cape of Good Hope. For he ſays, "Beſides Goold and Silver, there were brought to "the king, καὶ πολὺς Ἐλέφας, Αἰθιοπές, τε καὶ Πίθηκοι, *much Ivory, Ethio-* "*pians, and Monkeys.*"

R. Peritzol ‡ is guilty of the ſame miſtake; for he ſays, אופירה הכתוב בתורה הוא וגו "*Ophir, that is mentioned in Scripture, lies on the continent of the Interior Cuſh.*" And that he means by this Ethiopia, properly ſo called, appears from this very ſame chapter.

When he comes to ſpeak of *Taprobana*, he ſays §, אין כמוהו אלידה וגו "*There is none like it for ſize and goodneſs, as likewiſe the great number of* "*aromatic trees, and other ſorts of trees, that grow there. To which may* "*be added, rivers that afford gold-duſt, and, beſides theſe, precious ſtones.*"

Strabo ſpeaks of its ſize ‖, but ſays nothing of its productions.

Wherever this *Ophir* lay, it muſt have been a very rich country, as ſeems intimated by the very name itſelf. In the Hebrew language, the verb אפר *Aphar* is no-where read. But in the Arabic, the verb وفر, *Waphar* ſignifies *multus & copioſus fuit, abundavit*; and the participle وافر, *Waphir* is *abundans, copioſus, dives, opulentus*. And hence, with the proſthetic א after the Hebrew, and, perhaps, the Phœnician manner of forming ſuch kind of ſubſtantives, comes the word אופיר *Ophir*, which will ſignify, therefore, the ſame thing as *terra dives, auro abundans, &c.*

And with this will agree the other name of it, by which it was known to the Greeks, TAPROBANE. For in the Hebrew language, the word אבן *Eben*, and in the Chaldee, אבן *Eben* and אבנא *Abana*, ſignify a STONE; and ſo might the laſt word do likewiſe, in the Phœnician. If then from אפר *Aphar*, or ופר *Waphar*, they formed, according to their dialect, תופר *Thophar*, or תפר *Thaphar*, then תפר אבנא *Thaphar-abana*, or *Taprobana*, will be as much as to ſay, *a land rich in*, or *abounding with, ſtones that were precious.*

As to the modern name of this iſland *Ceylon*, it may be obſerved, that *Stephanus Byzantinus* ſays, that *Tabrobane* πάλαι μὲν ἐκαλεῖτο ΣΙΜΟΥΝΔΟΥ, νῦν δὲ ΣΑΛΙΚΗ, *was formerly called* Simundu, *but now it is called*

* Page 138. † Antiq. l. viii. c. 7. ‡ Page 98. § Page 174. ‖ Page 1012.

Salike. But whatever author this is quoted from, *Euſtathius* on *Dionyſius Perieget.* * read the direct contrary, "that it was formerly called *Salike*, "and afterwards *Simundu*." Inſtead of *Salike* (Σαλικὴ) Dr. *Hyde*, in his notes on *Peritzol* †, thinks the word ſhould be read (Σαλινὴ) *Saline*, which doth not differ much from *Selan*, or *Ceylon*; and Σιμούνδου, *Simundu*, or, perhaps *Silundu*, differs as little from *Selandiv*, *i. e.* the iſland *Selan*. For the termination *div*, in the Malabar language, ſignifies only an iſland.

From the time of *Solomon* we hear nothing of Navigation, till, as we are informed by *Herodotus* ‡, ſome Phœnician ſhips, by order of *Necho* king of Egypt, ſailed down the Arabian Gulph, and doubling the *Cape of Good Hope*, as it is now called, and ſailing through the ſtreights of *Gibralter*, in the third year arrived at Egypt. This was about the year before *Chriſt* 610, and conſequently about 2376 years ago.

Theſe were the firſt, as far as appears, that ſhewed the great continent of *Africa* to be bounded on the Weſt by the Sea.

The next account of ſailing round this continent, is in *Hanno*'s Periplus. This *Hanno* is, by Mr. *Dodwell* §, placed between Olymp. xcii. 4. and Olymp. cxxix. *i. e.* ſomewhere about the year before *Chriſt* 336. The Periplus, however, now extant, Mr. *Dodwell* thinks, is the work of ſome Greek, who was a friend to the Carthaginians, long after *Hanno*'s death, and different from the Periplus handed about among the ancients under the name of *Hanno*.

By *Necho*'s employing Phœnician ſhips, it ſeems as if they were, in thoſe days, better ſailors than the Egyptians; and when they returned home, they might bring an account of land lying beyond the continent of *Africa*, and the Phœnicians themſelves, afterwards, might ſend ſhips in ſearch of it through the Streights of *Gibralter*.

This land they might find to be an iſland, or iſlands, which they might call הן ארץ *Hen-ara*, i. e. *the beauty of land*, from the richneſs and fertility of the ſoil, and the temperature of the air. From hence the Greeks, by ſoftening the Phœnician words, formed their Καναρία Νῆσος, and hence likewiſe they came to call theſe Iſlands Εὐδαίμονες Νῆσοι; and this, we ſee, gives a better reaſon why theſe Iſlands are called the *Canary Iſlands*, than that given from *Can*, which, in Spaniſh, is ſaid to ſignify a *Dog*; becauſe the Spaniards found great numbers of dogs there when they diſcovered them afterwards ‖.

* Page 110. † Page 25. ‡ Page 235. § In his Diſſert. &c. p. 29.
‖ Gordon's Geograph. Gram. p. 338.

This

This was the fartheſt land the Phœnicians, and from them the Greeks, knew weſtward; and therefore *Ptolemy* reckons his Longitudes from thence.

From the account given by *Herodotus*, it appears, that the Phœnicians only coaſted, as indeed it is not conceivable how they could do otherwiſe before the invention of the Compaſs, when they would not venture out of ſight of land. Suppoſe then that they ſailed in the middle between the continent and the iſland *Fortaventura*, they would be about fifty Engliſh miles from it. The hills there are probably very high; ſuppoſe only one-eighth of a German mile, or a little more than half an Engliſh mile, then, by the table in *Varenius* *, we ſhall find that ſuch a hill may be ſeen at the diſtance of ſixty-eight Engliſh miles, which is more than ſufficient; but if we allow for *refractions*, we need not ſuppoſe the height of the hills there to be near ſo much.

Sailors affirm, ſays *Varenius* †, that they can ſee the Pike of *Teneriff* at the diſtance of four degrees in the Meridian: this, as he obſerves, will make its height equal to two German miles, or about nine miles one-third Engliſh, which is incredible. He ſuppoſes, therefore, after making proper allowances for refractions, and the inaccuracy of ſailors obſervations, that it may be ſeen at the diſtance of two degrees and a half, and therefore its altitude to be equal to one German mile; in which caſe, by his table, it may be ſeen at the diſtance of forty-one German miles and a half, or one hundred and ninety-three miles two-thirds Engliſh.

But the diſtance between *Teneriff* and Cape *Bojador*, according to modern Maps, is but little more than 150 Engliſh miles, and therefore *Teneriff* was undoubtedly ſeen by *Necho*'s Phœnicians; beſides, at that time, perhaps, it might be more viſible, as it might have been formerly a burning mountain. This is affirmed by *Scaliger* to have been the caſe; but *Varenius* ‡ ſays, he knows not upon what authority. That it was ſo, however, is confirmed by Mr. *Edens*, who was there in the year 1715.

In the *London Evening-Poſt* of *February* 10, 1761, it is ſaid, that "the Daniſh miſſionaries on the coaſt of *Malabar* have there met with "an ancient manuſcript in the ſacred language of that country, which "gives a very copious and diſtinct account of the commerce of the "Eaſt. It appears from thence, that the iſland of *Sielendive*, the *Taprobane* of the ancients, and now called *Ceylon*, was, in the fourth and

* Geog. vol. i. p. 126. † Vol. i. p. 124. ‡ Vol. i. p. 143.

"fifth

" fifth centuries, the great mart of the *Indies*, to which the merchants " from *Bengal*, *Malacca*, the *Moluccas*, and *China* reſorted; there ſold " their rich wares to the European traders, who came from *Egypt*, " *Arabia*, and *Perſia*, and who tranſported their goods by land to *Alex-* " *andria* and *Conſtantinople*."

Though little credit, in general, is to be given to reports in public News-papers, yet this ſeems not improbable, and may, perhaps, be one day or other confirmed by the gentlemen ſent into the Eaſt by his Daniſh majeſty.

From the time of *Necho* the Navigation of the weſtern coaſt of *Africa* was neglected, as far as appears, till A. D. 1494.

Bartholomew de Diaz firſt diſcovered the *Cape of Good Hope* A. D. 1481; and it was ſo named by *John* II. king of *Portugal*, then reigning. But *de Diaz* did not double that *Cape*, for want of proviſions, and by reaſon of the tempeſtuous weather which he met with.

But in 1497, in the reign of *Emanuel*, *Vaſques de Gama* doubled the *Cape of Good Hope*, and arrived at *Calicut* in *Indoſtan*.

And A. D. 1517, *Fernand Perez d'Andrade* was the firſt Portugueſe that went to *Canton* in *China*.

But to return to *Solomon's Ophir*.

Wherever this is to be placed, it appears, that in thoſe early days of Navigation it was a three years voyage. Nor is this to be wondered at, conſidering, that before the invention of the Mariner's Compaſs, men hardly ventured out of ſight of land. The *Magnet*, or *Loadſtone*, appears to have been known to the Greeks, as early, at leaſt, as the time of *Plato* and *Ariſtotle* *. But they knew no more of it than that power which may be called its

ATTRACTIVE POWER.

But who applied it firſt to the purpoſes of Navigation, is uncertain: that, however, could not be done, before the other and more principal properties of it were diſcovered.

But before we come to ſpeak of them, it will not be amiſs to add ſomething on the

NATURAL HISTOTY OF THE MAGNET.

The *Magnet* is found in many parts of the World, and moſt commonly in iron-mines. It is a kind of iron ore; and in ſome parts of

* See Plato's Ion.

Germany

Germany they run iron from it. When placed in the focus of a large Burning-glaſs, it manifeſtly diſcovers iron. Ruſt, moiſture, long diſuſe, and fire, weaken its force; though Mr. *Boyle* gives inſtances of ſome Engliſh *Loadſtones* which retained their virtue after ignition *.

The firſt and beſt ſort of theſe ſtones comes out of the *Eaſt-Indies*, from the coaſt of *China* and *Bengal*, and is of an iron or bloody colour. Theſe ſtones are very maſſy and weighty, and will lift up their own weight of iron, or ſteel, if the Stone itſelf doth not exceed a pound weight.

Theſe are the fineſt ſort, and are commonly ſold in the *Eaſt-Indies*, where they grow, for their own weight in ſilver. The beſt and fineſt are very rare to be found; for it is commonly a ſingle Stone, lying by itſelf in the Earth, and no ſhell, or piece of another.

There is another ſort, of a reddiſh colour, found in *Arabia* and the *Red Sea*, growing broad and flat like a tile or ſlate. This ſort is not ſo heavy as that of *China*; but is ſaid to be near as good, and its virtue to continue long on the Compaſs, or Needle, that is touched with it.

There is likewiſe another ſort of theſe Stones found in the *Levant*, in the iſle of *Elba*, hard by a town in that iſland called *Porto Ferraro*, from whence they are brought, every day, by our mariners. They are called in the country *Calameta Prita*, or the *Black Magnet*, to diſtinguiſh it from another ſort called *Calamita Blanca*, which is like a piece of dry fuller's earth, *white and light*. It is always found along with the other, ſticking faſt on its outſide like clay.

The uſe of this *white ſort* is prohibited in that country, becauſe it is ſometimes made uſe of for improper purpoſes.

The black Stones of *Elba*, juſt mentioned, have a mixture of white veins, and their force is neither very great, nor very laſting.

That ſort of Magnet, which was ſaid at firſt to be found in *Germany*, is full of holes like a honey-comb, and, though lighter in weight than the others, are yet very good. They are of an iron colour.

There is another bad ſort found in the iron-mines of *Norway*, as in *Longsound*, and other places. Their colour is black, mixed, or interlarded, with grey.

There is another ſort, of a grey colour, but of no great virtue, found in *Spain*. They are brought down on horſes to *Seville* and *Cadiz* to be ſold, and frequently to *Valencia*, *Alicant*, and *Liſbon*.

* Shaw's Boerhav. Chemiſt. vol. i. p. 134.

Notwithſtanding

Notwithſtanding what hath beeen ſaid of a ſort of Magnet found in *Arabia* and the *Red Sea*, yet it doth not appear that the *Arabians*, or *Jews*, knew any thing of its *attractive virtue*, but from the *Greeks*. It is no-where mentioned in Scripture. Dr. *Hyde* ſays *, that in the *Talmud* in the *Gemara* it is called אבן שואבת *Ebn-ſhoebeth*, i. e. *Lapis attrahens*. But the *Jeruſalem Talmud* was not compoſed till about the time of the emperor *Commodus*; about the year after Chriſt 300, ſays Dr. *Prideaux* †. But this is long enough after the *Greeks* knew that property of it.

Dr. *Hyde*, in the place above quoted, adds, *In Judæorum antiquiſſimis precibus vocatur* מגנים *Magnes* & קלמיטה *Kalamita*. And for the firſt of theſe names, *Buxtorf* (*in voc.*) quotes *Ikkarim*, *Orat.* iv. cap. 35; and for the laſt, *Ikkarim*, *Orat.* i. cap. 17. But it is evident the firſt of theſe words is Greek, and the ſecond Italian. From whence one may reaſonably collect, that theſe Jewiſh prayers, where they are mentioned, are not very old.

Neither have the *Arabians* any name, properly their own, for this Stone. *Schindler*, in his Lexicon, has حجر المس *Hajar al-mus*, i. e. *Lapis contactûs*; which he explains by *Magnes*, but cites no authority for the appellation. It is certain the moſt uſual name they have for it is مغنطيس *Magnetis*, the only word for it in *Golius*. And ſo *Schindler* quotes the Arabian geographer, as ſpeaking of حجر المغنطيس الذي يجذب الحديد اليه *the Stone Magnet, which attracts iron to itſelf*. But this name is apparently borrowed from the *Greeks*.

We may now proceed to obſerve, that though the attractive power of the Loadſtone, or Magnet, as hath been already ſaid, was known to the ancient *Greeks*, yet that other property of it, whereby it diſpoſes not only *itſelf*, but all *wires, and long pieces of iron*, touched by it, to lie along the Meridian of any place, ſo as to point nearly North and South, was intirely unknown to them. This may be called its

DIRECTIVE POWER.

The only thing that ſeems capable of being miſtook for ſome ſuch knowledge, is what *Jamblichus* tells us, in his life of *Pythagoras* ‡, Τοῦτον ὃν τὸν Ἄβαριν παρελομενός, ὃν ἔιχε, χρυσοῦν ὀιϛὸν, ὃ ἄνευ, ὑϕ' ὅιός τ' ἦν τὰς ὁδοὺς ἐξευρίσκειν, &c. *That* Pythagoras *took from* Abaris *the* Hy-

* In his Append. to his Relig. Antiq. Perſ. p. 495. † Connect. part i. book 5.
‡ Page 119. Ed. Kuſter.

perborean

perborean *his* golden dart, *without which it was impoſſible for him to find his road.*

By this one would be apt to ſuſpect, was there any room to think ſo, from other authors, that this property we are now ſpeaking of was known as early as this, and that *Abaris* travelled by the help of a *magnetical Needle*, here called *a Dart*, and ſtiled *a golden one*, on account of its uſefulneſs. But *Porphyry*, in his life of *Pythagorus* †, makes the ſtory yet more wonderful, and ſays, that *Abaris* uſed to *fly in the air*, οἰ᾽ῳ̃ τῷ̃ ἐν Ὑπερβορέοις Ἀπόλλωνος, δωρηθέντι αὐτῷ, ἐποχούμενος, *being carried on the dart given him by the* Hyperborean Apollo. And he farther adds, *that ſome people were of opinion* Pythagoras *could do the like.*

But both theſe authors are ſo late, and of ſo little credit in a ſtory of ſuch a blind nature, that nothing can be concluded from them with any certainty.

Who it was that diſcovered this power, is unknown. But nothing relating to this occurs in any European author before A. D. 1260. when *Paul* the *Venetian* brought in the uſe of the

MARINER's COMPASS,

as it is now commonly called. But this, it is ſaid, was not his own invention, but borrowed from the *Chineſe*, who had it long before.

If Father *Gaubil* ‡ was not impoſed upon, this directive power of the Loadſtone was known to the *Chineſe*, under the dynaſty of *Han*, which ended as early as the year after Chriſt 225, or above 1000 years before *Paul* the *Venetian* was in *China*.

But the Abbè *Renaudot*, in his diſſertation on the time when the Mohammedans went firſt into *China*, hath given very ſtrong reaſons againſt the antiquity of the Mariner's Compaſs in the Eaſt; and concludes, that the *Chineſe* knew nothing of it till it was introduced there by the *Europeans*.

Vertomanus affirms, that when he was in the *Eaſt-Indies*, about A. D. 1500, he ſaw the pilot of a ſhip direct his courſe by a Compaſs, framed and faſtened as thoſe commonly made uſe of in *Europe*.

But this account muſt be received with ſome caution; for, near 100 years after this, Mr. *Barlow*, in his *Navigator's Supply*, A. D. 1597, ſays, that in a perſonal conference with two *Eaſt-Indians*, he was told by them, that inſtead of our Compaſs, they made uſe of a *magnetical*

† Page 35. ‡ Obſervat. tom. ii. p. 95.

Needle of ſix inches, or longer, ſet upon a pin, in a diſh of white China earth filled with water: that in the bottom of this diſh they had two croſs lines, to mark the four principal winds; and that the reſt of the diviſions were left to the ſkill of their pilots.

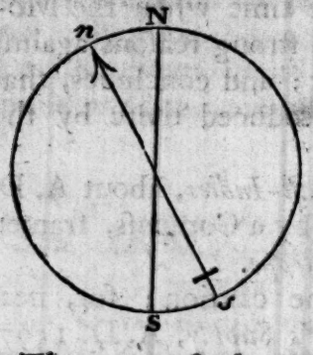
Since, therefore, we find ſo much uncertainty, with regard to this very uſeful invention, in the Eaſt, let us return to *Europe*.

And here, according to an old French poet, who wrote A. D. 1180, and cited by M. *Perrault*, in his *Parallel between the Ancients and Moderns*, the Mariner's Compaſs was known in the South of *France* as early as this; for he ſays, as his lines may be tranſlated,

There is a Star that never moves,
And an Art that never deceives,
By virtue of the Compaſs;
An ugly black Stone,
Which always attracts iron.

John Goia, however, a *Neapolitan*, in the year 1300, is generally looked upon as the author of the Mariner's Compaſs, and the firſt perſon that applied it to the navigating ſhips in the *Mediterranean*.

Though the *directive power* of the magnetical Needle was diſcovered, and applied, as above, yet it doth not appear, that during the fourteenth and fifteenth centuries, there were any apprehenſions of its pointing any other ways than due North and South. And whenever it was found *not* to do ſo, it was ſuppoſed to be owing to ſome error, or defect, in placing the wires, or to the ill make of the particular Compaſs in which it was obſerved, and not as ariſing from any thing real in nature.



This declination of the Needle from the true points, North and South, N. S to *n. s*, is called

THE VARIATION.

This variation of the Compaſs is ſaid to have been firſt obſerved by the famous *Chriſtopher Columbus*, a *Genoeſe*, in his voyage (*Auguſt* the 3d, 1492 *) for the diſcovery of that part of the World which is now called the *Weſt-Indies*.

The greateſt dependance of our Engliſh ſeamen now (for knowing when they are near the *Cape of Good Hope*) is, ſays Captain *Dampier*, upon their obſerving the variation of their Compaſs; which is very

* See European Settlements in America, p. 9.

carefully

carefully minded, when they come near the *Cape*, by taking the Sun's amplitude mornings and evenings. This they are ſo exact in, that by the help of the Azimuth Compaſs, an inſtrument *more peculiar* to the *ſeamen of our nation*, they know when they are a-breaſt of the *Cape*, or are either to the Eaſt or Weſt of it *.

But the firſt perſon that diſcovered this variation to be *real*, and that it was the ſame to all Needles in the ſame place, is generally allowed to have been *Sebaſtian Cabot*, a *Venetian*, or, as others ſay, the ſon of a *Genoeſe* merchant, and born at *Briſtol*, where his father was ſettled. This was about the year 1497.

If Father *Gaubil* was not impoſed upon, the *Chineſe* knew this variation long before, or as early as A. D. 1101 †.

And yet the *Chineſe* told another *Jeſuit* (Father *Le Compte*), that they knew nothing of any variation that the Needle had ‡.

And this is the more probable, as the variation in thoſe Seas is ſaid to be, in reality, very little, if any at all.

After the variation was diſcovered by *Cabot*, as was ſaid, to be *real*, it was thought, for a long time, to be *conſtant*, or *invariably the ſame*, at the *ſame place*, in all ages. But at laſt it was found to be *different*, at *different times*, in the ſame place; and this is called the

VARIATION OF THE VARIATION.

This was a diſcovery of Mr. *Gellibrand*, one of Sir *Thomas Greſham*'s Profeſſors at *Greſham* College, about A. D. 1625, according to Dr. *Wallis* §.

He got a large concave Dial to be erected in the Privy Garden at *Whitehall*, with great care, to fix a true Meridian line, and fitted with a large magnetic Needle of three feet length, the diameter of the concave, to ſhew the variation from that Meridian, as it altered from time to time.

The variation, as taken by that inſtrument, was, according to Mr. *Bond*, in his *Longitude found* ‖.

So that in that year's time the variation had proceeded 13′ 6″ to the weſtward. And there can be no doubt of the accuracy of the obſerva-

A. D. 1665, *June* 8 - - -	1° 22′ 30″ Weſt.
A. D. 1666, *June* - - -	1° 35′ 36″ Weſt.

* Voyage round the World, vol. i. p. 531. † See Obſervations, &c. tom. ii. p. 100.
‡ Ib. p. 101. § Philoſ. Tranſ. No. 276—278. ‖ P. 13, 14.

tion, as it is ſaid to have been made by ſome of the beſt obſervers of that age.

Under this head of the *variation* of the Needle, it will not be improper to obſerve, that there is this farther remarkable property belonging to it; which is, that when it is poized in the exacteſt manner poſſible, ſo as to lie on the pin that ſupports it truly horizontal, yet, upon touching it with the Loadſtone, it will loſe its equilibrium, and one end will dip towards the Earth; and is therefore called

A DIPPING NEEDLE.

This property of the Needle is ſaid to have been the diſcovery of an Engliſhman, one *Robert Norman*, a Compaſs-maker at *Wapping*, in the ſuburbs of *London*, about the year 1576.

As the horizontal Needle is obſerved to have different degrees of variation, or declination, from the Meridian, at different places, ſo the angle made with the perpendicular, by the dipping Needle, at different places, is found to be different.

Nay, what is more, Mr. *Graham* ſays, that he had diſcovered a certain *horary inequality*, both in the variation and dip of magnetic Needles, at one and the ſame place, and that, as far as to one-half or two-thirds of a whole degree *.

"And this laſt quantity (ſays Mr. *Whiſton*) I once obſerved myſelf in "a dipping Needle of my own, of almoſt *four feet* long, in the ſpace of "eight hours †."

As the quantity of the dip, at *different places*, was obſerved above to be *different*, it muſt be further remarked, that, near the Equator, the dipping Needle acquires an horizontal ſituation; and at *Cape Diggs*, in *Hudſon's Streights*, in about 62° of North latitude, and 79° of weſtern longitude from *London*, it ſtood perpendicular ‡.

In like manner, the horizontal Needle, in ſome places, points indifferently to all quarters of the Heavens, loſing intirely its directive virtue.

Captain *Taſman*, A.D. 1642, obſerved, that not very far Weſt from *Van Diemen's Land*, which, in Maps, is placed in about 142° of lon-

* See Philoſ. Tranſ. No. 383. † See Memoirs of himſelf, vol. i. p. 253.
‡ See Whiſton's Pref. to his Longit. found by Jupiter's Satellites.

gitude

gitude East from *London*, and about 42° of latitude South, it would not ſtand ſtill upon any particular point of the Compaſs *.

And Mr. *Pound* and Mr. *Cunningham*, in their voyage to the *Eaſt-Indies*, A. D. 1700, obſerved, that near the Iſland of *Jerſey*, and in the *Eaſt-Indies*, near the great *Cardomum Iſland*, in the Streights of *Malacca*, and on a rock at *Pulo Condore*, their common Compaſs would turn ſeveral ways †.

The like was obſerved too by Mr. *Ellis*, in his account of the laſt expedition in the *Dobbs* and *California*, for finding a North-Weſt paſſage, when they were about 90° Weſt from *London*, and 28° diſtant from the North Pole ‡.

The polarity of the Needle likewiſe has been found to have been deſtroyed by lightning; an inſtance of which may be ſeen in the *Philoſophical Tranſactions*, N° 492.

And another inſtance of the ſame effect of lightning on the Mariner's Compaſs, I had myſelf from Captain *Cooper*, commander of the *Townſend* Packet at *Falmouth* in the year 1739, upon his own knowledge.

As we have ſeen that the Mariner's Compaſs is ſubject to a variation, and that this variation is not the ſame at all times and places, it will be frequently neceſſary, at land, as well as at ſea, to know *what* that variation is, or how much the Needle declines from the Meridian of the place where we are.

If this variation be ſought at land, it may be found, by having, firſt, a Meridian line. How this may be drawn, therefore, is the next thing to be conſidered. But this will not improperly introduce the following

PROBLEM.

The Sun's azimuth being given, to place the Meridian of the Globe due North and South, or to find a Meridian line when the Sun ſhines.

Let the Sun's azimuth be 30° South-eaſterly; ſet the Horizon of the Globe upon a level, and bring the North Pole into the Zenith; then turn the Horizon about, until the ſhade of the axis cuts as many hours as is equivalent to the Azimuth (allowing 15° to an hour) in the North-Weſt part of the hour-circle, *i. e.* in this inſtance two hours, and therefore it will fall upon ten at night. This being done, the Meridian of the Globe ſtands in the true Meridian of the place.

* Sir John Narborough's Voyages, p. 132. † Whiſton, ut ſup. p. 104.

‡ See the Account, p. 221.

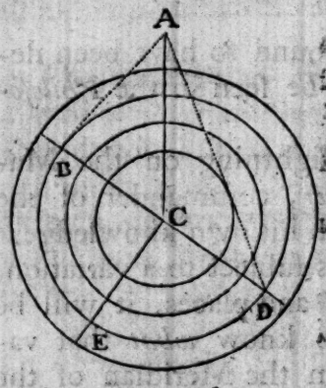
The

The Globe ſtanding in this poſition, if you hang two plummets at the North and South points of the wooden Horizon, and draw a line betwixt them, you will have a Meridian line.

This Problem ſuppoſes the Sun's azimuth already known; the difficulty of knowing which, without a calculation, and of ſetting the Globe upon a true level, makes this method of finding a Meridian line far from exact.

PROBLEM.

Another manner of drawing a Meridian line.



From C, as a center, deſcribe as many concentric Circles as you pleaſe. Erect the pin CA from C truly perpendicular, and obſerve the point D in the Circle BED, where the ſhadow of the pin falls before noon.

In the afternoon obſerve when the ſhadow of the pin falls at B in the ſame Circle.

Divide the arch BED in two equal parts in E, and draw the line CE; that will be the Meridian line ſought.

As this is the foundation of all aſtronomical Obſervations, the greateſt exactneſs poſſible is to be uſed in drawing this line. For without having the true Meridian of the place where we live, we ſhall not be able to determine its Latitude, or the height of the Pole there, which is equal to it; and without this, there is no inveſtigating the moment when the Sun enters the equinoctial, or ſolſtitial points, and conſequently no finding the length of the tropical year. But to find this Line, as all times are not alike, we are to chuſe the moſt proper.

The propereſt time, therefore, for doing this, will be when the Sun hath ſo great an altitude, as to be out of the power of refraction, which in the morning may be different from that in the afternoon, though the Sun is at the ſame diſtance from the Meridian; conſequently the apparent heights of the Sun, at thoſe two times, will be different, and the lengths of the ſhadows CB, CD, depending upon thoſe heights, unequal.

Beſides this allowance to be made for refractions, it is farther to be conſidered, that the Sun hath an apparent motion of his own, in the Ecliptic, ariſing from the real motion of the Earth. By this means, the declination of the Sun will be increaſing, or decreaſing, every moment.

Upon this account, the Sun's altitude, at two o'clock in the afternoon, will not be preciſely the ſame that it was at ten o'clock in the morning, though

though the Hour-circles themſelves, which the Sun is then in, make equal angles with the Meridian.

This change of declination is greateſt when the Sun is in the equinoctial points ♈ and ♎, and leaſt when he is in the ſolſtitial points ♋ and ♑; for then the Ecliptic becomes, as to ſenſe, parallel to the Equinoctial.

On account, therefore, of this great change in the Sun's declination, the time of the Equinoxes is improper for drawing this Meridian line; ſo likewiſe is the time of the Winter Solſtice, on account of the great and uncertain refractions to which the Sun is then liable.

From whence it follows, that the time of the Summer Solſtice, when the Sun is neither liable to refaction, nor change of declination, is the only proper time for putting this method in practice.

Another method is, by obſerving the Azimuth, or Altitude, of any known Star, that is high enough to be out of the power of refraction before it paſſeth the Meridian. Obſerve alſo, after it hath paſſed the Meridian, when it comes into the ſame Azimuth again, or to have an Altitude equal to the former. The diſtance between theſe two Azimuths, or equal Altitudes, biſected, will be in the plane of the Meridian.

At the Inſtrument-makers may be had inſtruments called

EQUAL ALTITUDE INTRUMENTS,

for obſerving Stars of equal heights; with which, having a good portable Pendulum, the Meridian and Latitude of any place may be very accurately found.

In what manner the time of noon, found by equal Altitudes of the Sun, before and after noon, may be corrected, may be ſeen in the *Connoiſſance des Temps*, for the year 1759 *.

There is another method of finding a Meridian Line by the Pole Star, which is this.

The right aſcenſion of the Pole Star, for the year 1716, was 37′ in time; and it increaſeth 1′ 16″ every ten years; therefore having, at any time, this Star's right aſcenſion, and the right aſcenſion of the Sun, both in time, if you ſubtract the latter from the former, adding twenty-four hours to the right aſcenſion of the Pole Star, when it is leſs than the Sun's, the remainder will be the time of the Star's coming to the Meridian.

At this time hang up two Pendulums, between your eye and Pole Star, and a right Line drawn through them, will be a true MERIDIAN LINE.

* Page 190.

EXAMPLE.

EXAMPLE.

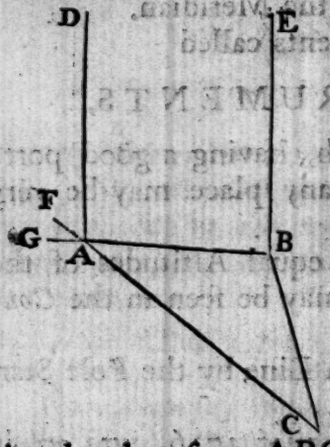
Right aſcenſion of the Pole Star for A. D. 1756 -	$00^h\ 42'\ 04''$
Sun's right aſcenſion (ſuppoſe) greater than the Star's; therefore add - - - - - - -	$24^h\ 00'\ 00''$
The Sum - -	$24^h\ 42'\ 04''$
Sun's right aſcenſion *November* the 30th - -	$16^h\ 29'\ 09''$
The Pole Star will come to the Meridian at - -	$8^h\ 12'\ 55''$

That is, at 12′ 55″ paſt eight at night.

What hath here been ſaid on the methods of drawing a Meridian Line, will naturally introduce the following

PROBLEM.

A Meridian Line being given, to find the Azimuth of any Star by obſervation.



Let AC be the Meridian Line given, and at A let there be erected the perpendicular Line AD.

From A to B let there be drawn a right Line AB, in ſuch a manner, that if from B there be erected the Perpendicular BE, or a Line with a plummet be hung at E, ſo that the Star and the two Lines AD, BE, ſhall lie in one and the ſame right Line.

From the point B, to any point C, in the Meridian Line AC, taken at pleaſure, draw the right Line BC; then with a Scale of equal parts meaſure the three Lines AB, AC, BC. In the triangle, therefore, ABC, there will be given all the ſides, from whence will be found the angle BAC, equal to the Azimuth required.

For if the Meridian Line be ſuppoſed to be continued to F, and the Line BA to G, the angle FAG will be the Azimuth of the Star; but the angle FAG will be equal to the angle at the Vertex BAC *; therefore the angle BAC will be equal to the Azimuth. W. W. D.

And now we may proceed to ſolve the following Problems relating to the fixed Stars.

* By Elem. L. i. Prop. 15.

PROBLEM.

PROBLEM.

The Latitude of the place, the Sun's place, and the hour of the night being given, to find the Azimuth and Altitude of any known fixed Star.

Rectify the Globe for the Latitude of the place, and the Sun's place; turn the Globe till the hour-index points to the given hour; then fix the Quadrant of Altitude in the Zenith, and lay it over the Star, and it will ſhew the Altitude and Azimuth of it.

It was by obſerving the times of the riſings and ſettings of the fixed Stars, or the times of their culminating or paſſing the Meridian, that the ancients determined the hour or time of night: this appears from a paſſage in *Euripides*, and another in *Iſaiah*, which will be taken notice of hereafter. In the mean time we may take occaſion to introduce the following

PROBLEM.

The Latitude of the place, the Sun's place, and the Azimuth of any known Star being given, to find the hour of the night.

Having rectified the Globe for the Latitude of the place and the Sun's place, if the given Star be due North or South, bring it to the Meridian, and the index will ſhew the hour of the night.

If the Star be in any other direction, fix the Quadrant of Altitude in the Zenith, and ſet it to the Star's Azimuth in the Horizon; turn the Globe about until the Quadrant cuts the center of the Star, and then the index will ſhew the hour of the night.

But as it may poſſibly happen that we may ſee a Star, and would be glad to know what Star it is, or whether it may not be a new Star, or a Comet; how that may be diſcovered, will be ſeen under the following

PROBLEM.

The Latitude of the place, the Sun's place, the hour of the night, and the Altitude and Azimuth of any Star being given, to find the Star.

Rectify the Globe for the Latitude of the place, and the Sun's place; fix the Quadrant of Altitude in the Zenith, and turn the Globe, till the hour-index points to the given hour, and ſet the Quadrant of Altitude to the given Azimuth; then the Star that cuts the Quadrant in the given Altitude, will be the Star ſought.

Though two Stars, that have different right aſcenſions, will not come to the Meridian at the ſame time, yet it is poſſible that in a certain Latitude they may come to the ſame vertical Circle at the ſame time; and that conſideration gives the following

PROBLEM.

The Latitude of the place, the Sun's place, and two Stars, that have the ſame Azimuth, being given, to find the hour of the night.

Rectify the Globe for the Latitude, the Zenith, and the Sun's place; then turn the Globe, and alſo the Quadrant about, till both the Stars coincide with its edge; the hour-index will ſhew the hour of the night, and the place where the Quadrant cuts the Horizon, will be the common Azimuth of both Stars.

What hath been obſerved above, of two Stars that have the ſame Azimuth, will hold good likewiſe of two Stars that have the ſame Altitude. From whence we have the following

PROBLEM.

The Latitude of the place, the Sun's place, and two Stars, that have the ſame Altitude, being given, to find the hour of the night.

Rectify the Globe for the Latitude of the place, the Zenith, and the Sun's place; turn the Globe, ſo that the ſame degree on the Quadrant ſhall cut both Stars, then the hour-index will ſhew the hour of the night.

In the former propoſitions the Latitude of the place is ſuppoſed to be given, or known. But as it is frequently neceſſary to find the Latitude of the place, and eſpecially at ſea, how this may be found, in a rude manner at leaſt, having the time given by a good clock, or watch, will be ſeen in the following

PROBLEM.

The Sun's place, the hour of the night, and two Stars, that have the ſame Azimuth, or Altitude, being given, to find the Latitude of the place.

Rectify the Globe for the Sun's place, and turn it, till the index points to the given hour of the night; keep the Globe from turning, and move it up and down in the notches, till the two given Stars have the ſame Azimuth, or Altitude; then the braſs Meridian will ſhew the height of the Pole, and conſequently the Latitude of the place.

PROBLEM.

PROBLEM.

Two Stars being given, one on the Meridian, and the other on the East and West part of the Horizon, to find the Latitude of the place.

Bring the Star observed on the Meridian to the Meridian of the Globe; then keeping the Globe from turning round its axis, slide the Meridian up or down in the notches, till the other Star is brought to the East or West part of the Horizon; and that elevation of the Pole will be the Latitude of the place sought.

OBSERVATION.

From what hath been said, it appears, that if, of these five things, I. The Latitude of the place, II. The Sun's place in the Ecliptic, III. The hour of the night, IV. The common Azimuth of two known fixed Stars, V. The equal Altitude of two known fixed Stars, any *three* of them be given, the remaining *two* will easily be found.

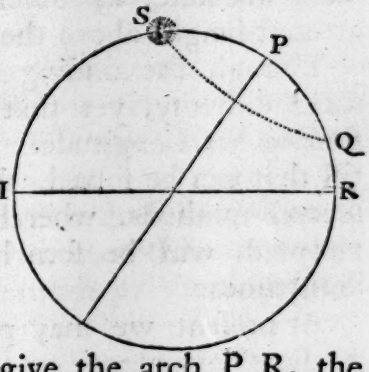
After what hath been seen relating to the motion of the Sun, and the risings and settings of the fixed Stars, we may now come, very properly, to solve the following useful Problem; and that is

TO FIND THE LATITUDE OF PLACES.

In what manner the Latitude of any place may be found by the Globe, hath been seen already. But in what manner the Latitude of any place may be found, so as to lay it down on a Map, or Globe, is a Problem of a different nature.

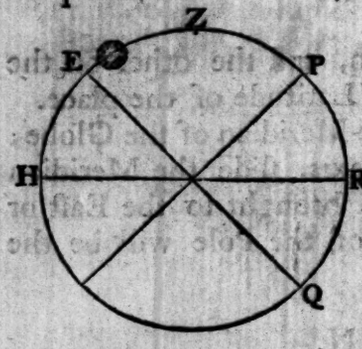
This is only to be done by observation; and that, either by NIGHT, or by DAY.

BY NIGHT.



Let HR be the Horizon of any place, and P the Pole; let S be any Star that never sets at that place. With any instrument, as a Quadrant, take the *greatest Altitude* of that Star, SPR, and again its *least Altitude*, QR; the difference between these two Altitudes will be the arch SQ, the half of which will be PQ, which added to the *least Altitude*, QR, will give the arch PR, the height

height of the Pole; and therefore, what is equal to it, the Latitude of the place. W. W. F.



BY DAY.

Let HR be the Horizon of any place, P the Pole, Z the Zenith, PEH the Meridian, ⊙ the Sun; with an inſtrument, as a Quadrant, take the Sun's Meridian altitude, ⊙H, and by an Ephemeris find the Sun's declination for that day at noon; that will be the arch ⊙E, which, ſubtracted from the Sun's Meridian altitude ⊙H, will give the arch EH, the height of the Equator at that place. This again ſubtracted from ZH = 90° will give the arch EZ, the Latitude of the place. W. W. F.

If the Sun's declination had been South, it muſt have been added to his Meridian altitude to give the height of the Equator.

Though the finding the Latitude of places be very neceſſary at land, yet it is of more frequent uſe at ſea, as well for determining the place of the ſhip in the wide ocean, as for diſcovering the variation of the Compaſs, as we ſhall preſently ſee.

The firſt of the two methods, given above, is impracticable at ſea; becauſe between the times that any Star will arrive at its *greateſt* and *leaſt Altitude*, the ſhip will have conſiderably altered its *Longitude*, or *Latitude*, or both.

The ſecond method depends upon having a good clock, or watch, in order to know the true time when the Sun is upon the Meridian.

Or the Sun's Meridian altitude may be found, nearly enough for common uſe, by *Davis's* ſea-quadrant, or Mr. *Hadley*'s Quadrant, which is more accurate, by obſerving, about noon, till the Sun comes to his greateſt height above the Horizon.

Though the finding the Latitude of a ſhip at ſea, is attended with ſome difficuty, yet that is nothing in compariſon of the difficulty of finding her Longitude. This is the great Problem in Navigation; and till that can be ſolved, the art can never be brought to perfection. The ſeveral methods, whereby the ſolution of this Problem hath been attempted, will be ſeen hereafter, when we come to ſpeak of more modern times.

At preſent we may proceed to another Problem, which hath an immediate dependance on the foregoing; and that is,

To

TO FIND THE VARIATION OF THE COMPASS.

Having ſpoke before of the variation of the Compaſs, it will not be improper, in this place, to obſerve in what manner that *variation* may be found; and in order to that, we muſt be furniſhed, in the firſt place, with an inſtrument called

AN AZIMUTH COMPASS.

The form of the inſtrument will be better known by a ſight of it, than by any deſcription.

There are ſeveral ways of finding the *variation* of the Needle, or Compaſs.

I. By the riſing and ſetting of the ſame Star, which will then be always at the ſame diſtance from the true Meridian; but the difference between that and the magnetical Meridian, will be the variation of the Compaſs.

II. By obſerving two equal Altitudes of the ſame Star above the Horizon; for then, likewiſe, it will be at equal diſtances from the true Meridian; and then the difference between that and the magnetical Meridian, will be the variation of the Compaſs.

III. By obſerving when any Star paſſes over the Meridian, for the reaſon before given.

But theſe methods can none of them be made uſe of at ſea.

Firſt, becauſe the time of the Sun's or any Star's paſſing over the Meridian, cannot be had preciſely enough; for a great deal of time muſt be ſpent in making obſervations on the Sun's different altitudes, till he is found to have the greateſt, *i. e.* till he is on the Meridian; and the ſame likewiſe may be ſaid with regard to any Star: and farther, while theſe obſervations are making, the ſhip may be changing her Longitude, *i. e.* altering her Meridian.

Secondly, becauſe between the times of two obſervations on the Sun's equal altitudes above the Horizon, or between the times of his riſing and ſetting, not only his declination, but likewiſe the ſhip's Latitude, may be conſiderably altered.

Thirdly, though the declination of a fixed Star doth not alter, like that of the Sun, yet between the times of any two obſervations on its riſing and ſetting, or its equal altitudes, the Latitude of the ſhip may be conſiderably altered.

The

The variation of the Compaſs at ſea, therefore, may be found, by means of the Azimuth Compaſs, by one obſervation on

I. THE SUN's MAGNETICAL AMPLITUDE.
II. THE SUN's MAGNETICAL AZIMUTH.

But for either of theſe obſervations the inſtrument muſt firſt be fitted in this manner.

I. If the Amplitude be at Sun-riſing, or the Azimuth before noon, put the center of the ſight upon the Weſt point of the card within the box, ſo that the *four lines* on card, and the *four lines* on the inſide of the box, may coincide, or agree together; the one directly over the other.

But if the obſervation be for the Sun's Amplitude at ſetting, or his Azimuth in the afternoon, then turn the center of the ſight right over the Eaſt point of the card, and make the *four lines* on the card coincide with the *four lines* on the inſide of the box, as before.

II. Having thus fitted the inſtrument for obſervation, turn the ſight towards the Sun, till the ſhadow of the hypothenuſal thread falls directly on the ſlit of the ſight, and upon the line that is drawn along the middle of the index; then will the index ſhew the Sun's magnetical Amplitude from the Eaſt or Weſt points, or his magnetical Azimuth from the North or South points of the Meridian.

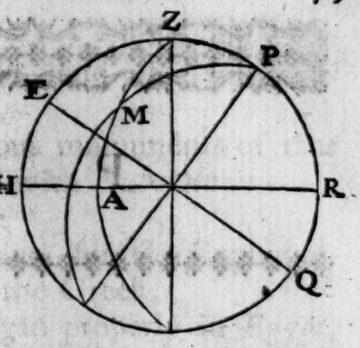
But it is here to be obſerved farther, that in order to have the Sun's true Amplitude, and from thence the difference between that and the magnetical Amplitude, and conſequently the variation of the Compaſs, we muſt have

I. The SUN's Declination, from Tables of his Motion.
II. The LATITUDE of the SHIP.

If we would have the Sun's true Azimuth, and from thence the difference between that and his magnetical Azimuth, and conſequently the variation of the Compaſs, we muſt have

I. The Latitude of the Ship, the Complement of which in this figure is Z P.
II. The Sun's Declination, whoſe Complement is PM.
III. The Sun's Altitude at the Time, the Complement of which is ZM.

Therefore,



Therefore, in the oblique-angled ſpherical triangle ZPM, there are given three ſides, ZP, ZM, PM, from whence may be found the angle MZP, the meaſure of which will be the arch of the Horizon AR; that will give the Sun's Azimuth from the north part of the Meridian, and the complement of this to 180 degrees, will be the Sun's Azimuth from the South.

If AR is greater than 90 degrees, then from AR ſubtract 90 degrees, and the remainder will be the Sun's Amplitude.

Find now the Sun's magnetical Azimuth, or Amplitude, by obſervation, and the difference, if there be any, will give the

VARIATION OF THE COMPASS.

An EXAMPLE will make this beſt underſtood.

Being out at ſea *May* 15, A. D. 1755, in Latitude 45 degrees North, by obſervation, let the Sun's magnetical Amplitude at riſing be obſerved, by the Azimuth Compaſs, to be between 27 and 28 degrees, reckoning from the Eaſt towards the North.

But, by calculation, let the Sun's declination be found, for that time, - - - - -	19° 00′ North
Whence in Latitude 45° North, his Amplitude ought to be - - - - - -	27° 25′
But, by obſervation, it was found about - -	27° 25′
Therefore, the variation of the Compaſs there is -	00° 00′

PART

PART III.

THE HISTORY OF ASTRONOMY, FROM THALES TO ALEXANDER THE GREAT.

EXCEPT what little hiſtory we know from the writings of the Old Teſtament, we are quite in the dark, as to any improvements made in arts and ſciences before the *Greeks* began to apply themſelves to the ſtudy of Nature. But this, as far as appears at leaſt, was not earlier than about the time of *Thales* the *Mileſian*, or the year before Chriſt 600. He was one of the firſt that is ſaid to have travelled into *Egypt*; a country, it ſeems, at that time famous for its wiſdom.

To enquire particularly wherein that wiſdom conſiſted, would lead us too far out of the way. But as no great proficiency in the ſciences, particularly Geography and Aſtronomy, is to be expected without Mathematicks, and all that we know of theſe came confeſſedly from the *Greeks*, the world hath been generally inclined to believe, that theſe laſt borrowed more from the *Egyptians* than, with good reaſon, they ſeem to have done.

Herodotus *, and *Diodorus Siculus* after him †, agree, that GEOMETRY took its riſe among them, from the annual overflowing of the *Nile*; and that from them it was introduced into *Greece*.

* Page 127. † Page 73.

Diodorus

Diodorus Siculus * goes farther, and ſays, that the *Egyptians* were the *Inventors of Letters*,----of *obſerving the Stars*,-----and of *Geometrical Theorems*. But,

I. It doth not appear, from any of the numerous monuments of that people yet extant, that they were ever acquainted with ALPHABETICAL LETTERS.

This, it is plain, is ſaid of the native *Egyptians*; for the Coptic alphabet is indiſputably modern, and derived from the Greek.

II. That the practice of obſerving the Stars began properly in *Egypt*, is wholly uncertain. *Muſeus*, *Endymion*, *&c.* ſpoke of by the *Greeks* as obſervers, ſeem to have lived long before it appears that they had any intercourſe with *Egypt*, which, according to *Herodotus*, was not before the reign of *Pſammiticus*, the father of *Necho*, who conquered *Joſiah* king of *Judah*, *i. e.* about the year before Chriſt 670.

Beſides, the names of the oldeſt Conſtellations, as given us by the *Greeks*, ſeem rather to have a Chaldean, or Phœnician original, than an Egyptian. The only Star that ſeems to retain its Egyptian appellation, is the *Canopus*, from Χνῶβ, which, in the Coptic, ſtill ſignifies *gold*: and it is farther obſervable, that there is not one Eclipſe extant, obſerved by the native *Egyptians*, or before the *Greeks* ſettled themſelves in their country under the *Ptolemies*.

III. There do not appear, on any of their pillars, or obeliſks, or on the walls of their temples yet ſtanding, any geometrical diagrams; which yet one would have reaſonably expected to have found, ſometimes at leaſt, had Geometry been a Science particularly cultivated by the *Egyptians*.

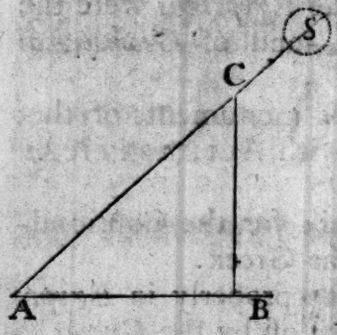
But our conceptions of them, in this reſpect, will be greatly abated, when we conſider, that thoſe propoſitions, which *Thales* is ſaid to have *invented*, or *borrowed* from them, do not exceed the *very firſt* elements of the Science; ſuch as, "that the Circle is biſected by its diameter." Likewiſe, "that the angles of an iſoſceles Triangle at the baſe are equal."

He is ſaid likewiſe, by ſome, to have been the inventor of that Propoſition which is now *Euclid*, Lib. i. Prop. 47. and by others attributed to *Pythagoras*.

Thales is likewiſe ſaid, by *Diogenes Laertius*, to have meaſured the heights of the pyramids in *Egypt*, by obſerving at what time of the day the ſhadows of objects are equal to their heights.

This is now known to be always when the Sun is 45 degrees high.

* Page 63.

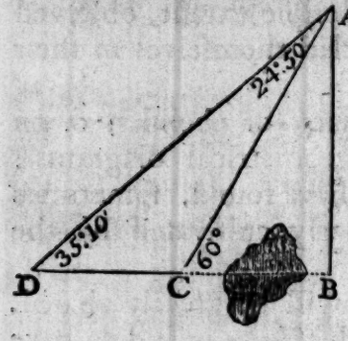


For the Angle CBA being a right Angle, and the Angle CAB = 45° ſince the the three Angles of a Triangle are equal to two right ones, the remaining Angle ACB will likewiſe be = 45°; therefore the Triangle ABC will be an iſoſceles Triangle, and AB = BC.

This method, though ingenious enough, yet is practicable only *twice* on the ſame day; and in ſome countries, in the Winter time, not at all, *i. e.* where the Sun doth not riſe ſo high above the Horizon as 45°.

This method likewiſe ſuppoſeth the foot of the object to be acceſſible, which is not always the caſe, and frequently where the perpendicular height of the object is moſt neceſſary to be known; ſuch may be the height of an enemy's rampart, a caſtle-wall, *&c.*

This Problem, therefore, being of ſuch general uſe, it will not be improper to ſee in what manner this defect may be ſupplied, by taking *two* ſtations inſtead of *one*.



Let AB be the perpendicular height of any object required, but which is acceſſible no nearer than C; at C, then, take with an inſtrument the Angle ACB (ſuppoſe) = 60°. From C meaſure backwards the Line CD (ſuppoſe) = 1000 feet; and at D take the Angle ADC (ſuppoſe) = 35° 10′.

In the Triangle, therefore, ADC there is given the Angle ADC = 35° 10′; and ſince the external Angle ACB was found to be = 60° the Angle DAC muſt be = 24° 50′; and ſince the ſide oppoſite to it DC is = 1000, it will be by Prop. iv. p. 6.

Sin. DAC : Sin. ADC : : DC (1000) : AC = 1371

Therefore the Line AC is given. Then ſay, ſince the Angle ACB was before given = 60°

Radius : Sin. ACB : : AC (1371) : AB = 1187

Therefore AB, the perpendicular height required, is given.

In the ſame manner may be found the perpendicular height of any Cloud.

Poſidonius,

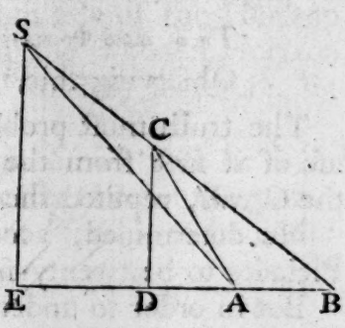
Poſidonius, a friend and acquaintance of *Cicero*'s, if we are rightly informed by *Pliny* *, ſuppoſed the greateſt height to which Clouds riſe to be forty ſtadia; that is, if we allow eight ſtadia to a mile, their greateſt perpendicular height will be five miles.

In what manner *Poſidonius* meaſured the height of the Clouds, is not known; but his concluſion is certainly very wide of the truth. For thoſe who have meaſured them with moſt exactneſs, have ſeldom found them to exceed a mile in perpendicular height.

Though the height of a Cloud, as was obſerved, may be very eaſily taken at two ſtations, yet Mr. *Horrox*, in his Poſthumous Works †, affirms, that he had a method whereby he could do the ſame at a ſingle ſtation; and that afterwards he had found the ſame method in *Kepler*.

That method, as it is not commonly known, and hath its elegance, is as follows.

Let S be the Sun, C a Cloud, and let the ſhadow of the Cloud be obſerved by a perſon at A to fall at B.



Let the obſerver at A take the height of the Sun, which will be the Angle SAE, and the height of the Cloud, which will be the Angle CAD.

But, becauſe of the immenſe diſtance of the Sun, the Angle SAE will not ſenſibly differ from the Angle SBE, which, therefore, will be given. But CAD, the external Angle of the Triangle CAB is given, and therefore the Angle ACB is given. But CAD being given, the Angle ACD will be given, and conſequently the whole BCD will be given.

Therefore, ſince it will be, by plain Trigonometry,

Tangent BCD ; Radius : : BD : DC
Tangent ACD : Radius : : AD : DC

By taking the differences of the antecedents, it will be,

Tangent BCD — Tangent ACD : Radius : : AB : DC

But the Line AB may be found by actual menſuration; conſequently the three firſt terms of the proportion being known, the fourth, that is, DC, the perpendicular height of the Cloud, will be given.

W. W. F.

* Nat. Hiſt. l. ii. c. 23. † Page 294.

Thales and his followers, according to *Plutarch* *, affirmed that the Moon borrowed her light from the Sun; and therefore *Plutarch* was probably miſtaken, or thoſe he copied from, when they repreſent the opinions of *Anaximander* and *Antipho* †, who lived after him, to be, that ſhe ſhone with a light of her own.

It may not be quite foreign to the purpoſe to remark in this place, that *Plutarch*, though a ſenſible author in other reſpects, yet hath collected this treatiſe, concerning the opinions of the ancient philoſophers, without choice, or examination, from writers that knew little of the ſubject they were upon. Inſtances likewiſe may be given, where, paſſing through very ignorant hands, he hath ſuffered greatly by interpolations and corruptions.

Thales is ſaid by *Callimachus* to have formed the Conſtellation called the *Leſſer Bear*, by which, according to *Aratus*, the *Phœnicians* ſailed.

Τῇ δ' ἄρα Φοίνικες πίσυνοι περόωσι θάλασσαν.

Obſerving this, *Phœnicians* plow the main.

The truth moſt probably is, that *Thales* brought the knowledge and uſe of it firſt from the *Phœnicians* himſelf into *Greece*; and ſo was, by the *Greeks*, reputed the original inventor of it.

He determined, according to *Pliny* ‡, the coſmical ſetting of the Pleiades to be twenty-five days after the *autumnal Equinox*.

But in order to underſtand this, it will be proper to obſerve, that there are three ſorts of riſings and ſettings of the fixed Stars, taken notice of by ancient authors, and commonly called *poetical riſings* and *ſettings*, becauſe moſtly taken notice of by the Poets. Theſe are the

COSMICAL, ACHRONYCAL, AND HELIACAL.

They are to be found in moſt authors that treat on the doctrine of the Sphere, and are now chiefly uſeful in comparing and underſtanding paſſages in the ancient writers; ſuch are *Heſiod*, *Virgil*, *Columella*, *Ovid*, *Pliny*, &c. How they are to be found by calculation, may be ſeen in *Petavius's Uranologion* and Dr. *Gregory's Aſtronomy*.

DEFINITION.

When a Star riſes or ſets at Sun-riſing, it is ſaid to riſe or ſet *coſmically*. From whence we ſhall have the following

* De Placit. Philoſ. l. ii. c. 28. † Ibid. ‡ Nat. Hiſt. l. xviii. c. 25.

PROBLEM.

PROBLEM.

The Latitude of the place being given, to find, by the Globe, the time of the year when a given Star riſes or ſets *coſmically*.

Let the given place be *Rome*, whoſe Latitude is 42 deg. 8 min. North; and let the given Star be the *Lucida Pleiadum*. Rectify the Globe for the Latitude of the place; bring the Star to the edge of the eaſtern Horizon, and mark the point of the Ecliptic riſing along with it; that will be found to be *Taurus*, 18 deg. oppoſite to which, on the wooden Horizon, will be found (in the *Julian Stile*) *April* the 28th. The *Lucida Pleiadum*, therefore, riſes coſmically *April* the 28th.

If the Globe continues rectified as before, and the *Lucida Pleiadum* be brought to the edge of the weſtern Horizon, the point of the Ecliptic, which is the Sun's place, then riſing on the eaſtern ſide of the Horizon, will be *Scorpio*, 29 deg. oppoſite to which, on the wooden Horizon, will be found *November* the 10th. The *Lucida Pleiadum*, therefore, ſets coſmically *November* the 10th.

In the ſame manner, in the Latitude of *London*, *Sirius* will be found to riſe coſmically *July* the 30th, and to ſet coſmically *October* the 30th.

It is of the *coſmical* ſetting of the *Pleiades* that *Virgil* is to be underſtood in this line,

Ante tibi Eoæ Atlantides abſcondantur *,

and not of their *ſetting in the Eaſt*, as ſome have imagined, where Stars riſe, but never ſet.

DEFINITION.

When a Star riſes or ſets, at Sun-ſetting, it is ſaid to riſe or ſet *achronically*.

Hence, likewiſe, we have the following

PROBLEM.

The Latitude of the place being given, to find the time of the year when a given Star will riſe or ſet achronically.

Let the given place be *Athens*, whoſe Latitude is 37 deg. North, and let the given Star be *Arcturus*.

* Georg. l. i. ver. 221.

Rectify

Rectify the Globe for the Latitude of the place, and bringing *Arcturus* to the eaſtern ſide of the Horizon, mark the point of the Ecliptic then ſetting on the weſtern ſide; that will be found *Aries*, 12 deg. oppoſite to which, on the wooden Horizon, will be found *March* the 22d. Therefore *Arcturus* riſes at *Athens* achronically *March* the 22d.

It is of this riſing of *Arcturus* that *Heſiod* ſpeaks in his *Opera & Dies* *.

When from the *Solſtice* ſixty days are paſt,
At eve *Arcturus* riſes in the Eaſt.

This, it is plain, doth not agree with the determination above, the reaſon of which will be ſeen hereafter.

If the Globe continues rectified to the Latitude of the place, as before, and *Arcturus* be brought to the weſtern ſide of the Horizon, the point of the Ecliptic ſetting along with it will be *Sagittary*, 7 deg. oppoſite to which, on the wooden Horizon, will be found *November* the 18th. At *Athens*, therefore, *Arcturus* ſets achronically *November* the 18th.

In the ſame manner *Aldebaron*, or the *Bull's Eye*, will be found to riſe achronically *May* the 11th, and to ſet achronically *December* the 8th.

DEFINITION.

When a Star firſt becomes viſible in the morning, after it hath been ſo near the Sun as to be hid by the ſplendor of his rays, it is ſaid to riſe *heliacally*.

But for this there is required ſome certain depreſſion of the Sun below the Horizon, more or leſs, according to the magnitude of the Star. A Star of the firſt magnitude is commonly ſuppoſed to require that the Sun be depreſſed 12 deg. perpendicularly below the Horizon.

This being premiſed, we have the following

PROBLEM.

The Latitude of the place being given, to find the time of the year when a given Star will riſe heliacally.

Let the given place be *Rome*, whoſe Latitude is 42 deg. North, and let the given Star be the *bright Star* in the *Bull's Horn*.

Rectify the Globe for the Latitude of the place; ſcrew on the braſs Quadrant of Altitude in its Zenith, and turn it to the weſtern ſide of the Horizon. Bring the Star to the eaſtern ſide of the Horizon, and

* Lib. ii. ver. 185.

mark

mark what degree of the Ecliptic is cut by 12 deg. marked on the Quadrant of Altitude; that will be found to be *Capricorn*, 3 deg. the point oppoſite to which is *Cancer*, 3 deg. and oppoſite to this will be found, on the wooden Horizon, *June* the 14th. The *bright Star*, therefore, in the *Bull's Horn*, in the Latitude of *Rome*, riſes heliacally *June* the 14th.

Theſe kinds of riſings and ſettings are not only mentioned by the Poets, but likewiſe by the ancient Phyſicians and Hiſtorians.

Thus *Hippocrates*, in his book *De Ære*, ſays, Δεῖ καὶ τῶν ἄστρων τὰς ἐπιτολὰς φυλάσσεσθαι καὶ μάλιστα τὴν κυνὸς, ἔπειτα Ἀρκτούρου καὶ ἐπὶ Πλειάδων δύσει, i. e. *One ought to obſerve the heliacal riſings and ſettings of the Stars, eſpecially the* Dog Star *and* Arcturus; *likewiſe the* coſmical *ſetting of the* Pleiades.

And *Polybius*, ſpeaking of the loſs of the *Roman* fleet, in the firſt Punic war, ſays, "it was not ſo much owing to fortune, as to the obſtinacy of the conſuls, in not hearkening to their pilots, who diſſuaded them from putting to ſea at that ſeaſon of the year, which was between the riſing of *Orion* and the *Dog Star*; it being always dangerous, and ſubject to ſtorms *."

DEFINITION.

When a Star is firſt immerſed in the evening, or hid by the Sun's rays, it is ſaid to ſet *heliacally*.

And this again is ſaid to be when a Star of the firſt magnitude comes within 12 degrees of the Sun reckoned in the perpendicular.

Hence again we have the following

PROBLEM.

The Latitude of the place being given, to find the time of the year when a given Star ſets heliacally.

Let the given place be *Rome*, in Latitude 42 deg. North, and let the given Star be the *bright Star* in the *Bull's Horn*. Rectify the Globe for the Latitude of the place, and bring the Star to the edge of the weſtern Horizon; turn the Quadrant of Altitude, till 12 deg. cut the Ecliptic on the eaſtern ſide of the Meridian. This will be found to be 7 deg. of *Sagittary*, the point oppoſite to which, in the Ecliptic, is 7 deg. of *Gemini*; and oppoſite to that, on the wooden Horizon, is *May* the

* Lib. i. p. 53.

17th,

17th, the time of the year when that Star now ſets heliacally in the Latitude of *Rome*.

It is of the heliacal ſetting of this Star, in a larger ſenſe of the word, or of the Sun's entering *Taurus*, that *Virgil* is to be underſtood *, where he ſays,

Candidus auratis aperit cum cornibus annum
Taurus, & averſo *cedens Canis occidit* aſtro.

It is to be obſerved, that the Sun now enters *Taurus*, *April* the 20th, N. S. or *April* the 9th, O. S. *Columella* ſuppoſed, that, in his time, he did ſo, *April* the 17th. *Ovid*, in his *Faſti*, makes it *April* the 19th; but the ancient Calendars, in this reſpect, are not very exact, being compoſed from obſervations, rude in themſelves, and made in different ages and different latitudes.

But the thing principally to be taken notice of at preſent, is, that the commentators are divided in their opinions, as to what is to be underſtood by the *averſum aſtrum* above. Some think it means *Argo*, or the *Ship*. But *Virgil* had not ſaid a word before about the Ship.

Others think the *Bull* itſelf is the Conſtellation meant. But the *Dog* ſets after the *Bull*, and therefore cannot, with any propriety, be ſtiled *Cedens*, *yielding to*, or *retreating from*.

But *Servius* takes notice, that, in his time, ſome copies read *adverſo*. This was about the time of *Theodoſius*, the Roman emperor, or about A. D. 340. And ſeveral copies now, as the Roman, the Lombard, the King's, one of the Arundelian, and both Dr. *Mead*'s MSS. ſtill retain *adverſo*; and therefore the lines will be,

Candidus auratis aperit cum cornibus annum
Taurus, & adverſo *cedens Canis occidit aſtro.*

Which lines are very properly tranſlated by the author of the *Eſſay on the Georgics*, thus,

When with his horns the *Bull* unbars the year,
And frighten'd flies the *Dog*, and ſhuns the *adverſe* Star.

Here, then, we have an inſtance of what uſe the knowledge of the Globes may be in correcting miſtakes crept into the ancient Poets.

There is another paſſage in the ſame poet †, which the Globe may likewiſe help to explain. *Petavius*, in his *Uranolog.* ‡ calls it *locus inextricabilis*.

* Georg. i. ver. 217. † Georg. iv. ver. 231. ‡ Page 95.

Virgil

Virgil ſays, there are two ſeaſons for gathering of honey. One ſeaſon is,

Taygete ſimul os Terris oſtendit honeſtum
Pleias, & Oceani ſpretos pede reppulit amnes.

That is, when the Pleiades roſe heliacally, which, according to *Columella*, was *April* the 22d.

The ſecond ſeaſon, he ſays, was,

Aut eadem ſidus fugiens ubi Piſcis aquoſi,
Triſtior hybernas Cœlo deſcendit in undas.

The general meaning of the lines, it is agreed, is, that it was when the Pleiades ſet coſmically, *i. e.* at the latter end of *October*, or the beginning of *November*. The difficulty is, to know what Conſtellation is meant, in particular, by *Piſcis Aquoſi*.

Servius (on the place) ſays, it is the *Southern Fiſh*, that receives the water of *Aquarius* into his mouth. The bright Star in the mouth of *this Fiſh* is now called, from the Arabian Aſtronomers, فوم الحوت *Fomahout*.

The reaſon given by *Servius* for his interpretation is, *becauſe this Fiſh riſes when the Pleiades ſet*. But this is not true; for when the Pleiades are ſetting, the Star called *Fomahout* is almoſt in the northern Meridian below the Horizon.

Father *Catrou* ſays it means *Piſces*, one of the twelve Signs of the Zodiac.

The objection to this interpretation is, in the firſt place, that the epithet *Aquoſus*, when applied to *Piſces*, ſeems hardly conſiſtent with the great delicacy of *Virgil*, obſervable every where in the choice of his epithets. In the ſecond place, the Conſtellation *Piſces*, being the laſt in the order of the twelve Signs, ſets before the *Pleiades*. The *Pleiades*, therefore, follow *Piſces*, and can never be ſaid to *ſhun* or *avoid* them.

La Cerda was of the ſame opinion with *Catrou*; but will not diſpute, he ſays, with any one that ſhall ſuppoſe it to be the *Dolphin*.

But when the *Pleiades* are ſetting in the Weſt, the *Dolphin* is yet below the Horizon in the Eaſt. Beſides, as *Petavius*, in the place above quoted, obſerves, the word *Fugere* is always uſed of ſome Conſtellation that is near.

Ruæus thinks the *Hydra* is meant; and Mr. *Dryden* calls it the *Scorpion*.

In the Latitude of *Rome*, indeed, when the *Pleiades* ſet, the *Scorpion* riſes; but it is hardly probable that *Virgil* ſhould call either the *Hydra*, or the *Scorpion*, *Piſces*.

Perhaps the line ſhould be read thus,

Aut eadem ſidus fugiens ORIONIS AQUOSI.

Orion is a Conſtellation near the *Pleiades*, and agrees with the obſervation of *Petavius*, before-mentioned. The ſame epithet *Aquoſus* is applied by *Virgil* himſelf to *Orion* *. He is likewiſe called *Nimboſus Orion* †. And *Quintus Calaber* ‡ not only repreſents the *Pleiades* as flying from *Orion*, but likewiſe makes the two firſt ſyllables of the word ΩΡΙΩΝΟΣ ſhort in quantity, as here.

Thales is the firſt perſon who is ſaid to have made uſe of the word ΤΡΟΠΑΙ, *Tropics*, i. e. was the firſt perſon, perhaps, who brought the *Greeks* acquainted with the true cauſe of the variety of ſeaſons, ariſing from the obliquity of the Ecliptic. From whence we have the following

PROBLEM.

To ſhew by the Globe the cauſe of the variety of the ſeaſons, ariſing from the obliquity of the Ecliptic.

SCHOLIUM.

Hence, ſince *Heſiod* makes uſe of the word ΤΡΟΠΑΙ, it ſeems to follow, that *Heſiod* could not be older than the time of *Thales*.

But *Homer* likewiſe § uſes the ſame word ΤΡΟΠΑΙ ΗΕΛΙΟΙΟ. And as this paſſage is pretty remarkable, it may help us to fix the date of *Homer's Odyſſey*, and illuſtrate the uſe which Aſtronomy may be of in Hiſtory and Chronology.

In the paſſage juſt cited *Ulyſſes* returns home, but is not known to any of his family. Upon meeting with *Eumæus*, who had the charge of his ſwine, and aſking him whether he was born in the family, or no, he anſwers him in the negative, and farther tells him, that he was born in the iſland *Syria*, or *Syra*.

Νῆσός τις ΣΥΡΙΗ κικλήσκεαι ἤιπυ ἀκούεις
Ορτυγίης καθύπερθεν, ὅθι ΤΡΟΠΑΙ ΗΕΛΙΟΙΟ.

* Æneid iv. ver. 52. † Æneid i. ver. 539. ‡ Lib. v.
§ Odyſſ. lib. xv. ver. 402.

The

The queſtion here is, what is to be underſtood by the words ΤΡΟΠΑΙ ΗΕΛΙΟΙΟ, *the Tropics of the Sun?*

It cannot mean that *Syra* lay under the *Tropic*, becauſe they knew that the Sun was never vertical there; for it is one of thoſe iſlands called the *Cyclades*, and lies in Latitude 37° 25′ North; and therefore the Sun's Zenith diſtance there, on the day of the Summer Solſtice, is 13° 56′.

It cannot mean, likewiſe, that the Sun *there*, in particular, entered the ſoſtitial point; becauſe he doth ſo to every place upon the Earth, only at different times of the day.

The true meaning, therefore, ſeems to be, that at *Syra* was erected an inſtrument to ſhew the time of the Sun's ingreſs into the *Cardinal Points*. And ſuch an inſtrument, we know from *Diogenes Laertius*, was erected at that place by *Pherecydes*.

And this naturally gives occaſion to introduce the following

PROBLEM.

To ſhew by the Globe the cauſe of the unequal increaſe and decreaſe of the days.

It is well known, that about the time of the Summer and Winter Solſtices, the days increaſe and decreaſe very ſlowly; and about the time of the two Equinoxes, they increaſe and decreaſe very faſt.

The reaſon is, that at the Tropics, the Ecliptic is nearly parallel to the Equinoctial; and conſequently, for ſome days before and after the Solſtice, the change in the Sun's declination is but ſmall. On the contrary, about the Equinoxes the angle made by the Ecliptic with the Equator is the greateſt, and conſequently the change in the Sun's declination is then the greateſt.

Thales is ſaid by *Plutarch* * to have been the firſt perſon (meaning, it may be ſuppoſed, among the *Greeks*) who taught that ſolar Eclipſes were cauſed by the interpoſition of the Moon's body between the Sun and the Earth.

That *Thales* was in ſome ſort acquainted with the nature of ſolar Eclipſes, appears from *Herodotus*, who ſays, that he foretold to the *Ionians* that Eclipſe which put an end to the war between the *Lydians* and *Medes*.

This, from ſeveral circumſtances, could be no other than the ſolar Eclipſe in the year before Chriſt 603.

* De Placit. Philoſoph. lib. ii. cap. 24.

Becauſe ſolar Eclipſes can now be predicted with great exactneſs, ſome perſons have ſuppoſed that *Thales* foretold not only the day, but the very hour and minute, when this Eclipſe was to happen.

But this is a miſtake; for *Herodotus* only ſays, that he foretold it would happen within the *compaſs of that year*.

But if ſolar Eclipſes were underſtood, at that time, in this manner, *Xenophanes*, after this, about the year before Chriſt 521, muſt have been greatly miſtaken, or miſrepreſented by *Plutarch*, when he delivers it as his opinion, that the Sun was intirely extinguiſhed when he was eclipſed, and a new one produced.

Much more probable is what *Plutarch* relates of him beſides, that he mentioned in his writings an Eclipſe of the Sun that laſted a whole month.

But darkneſſes of this kind are improperly called Eclipſes, not being cauſed by the interpoſition of the Moon's body, but proceeding from ſome real diminution of the Sun's light, whatever may be the cauſe. For the duration of total darkneſs, in the greateſt ſolar Eclipſe that can happen, never can laſt, at any particular place whatever, quite four minutes.

There are ſeveral inſtances of ſuch kind of darkneſſes to be met with in hiſtory; particularly that very remarkable one when *Julius Cæſar* was murdered in the ſenate-houſe, mentioned by *Virgil* *.

Cum caput obſcurâ nitidum ferrugine texit
Impiaq; æternam timuerunt ſæcula noctem.

Servius, in his note on this place, ſays, this darkneſs laſted *ab hora ſexta uſq; ad noctem, i. e.* from noon till night, which, at that time of the year, muſt have been ſix hours.

Another moſt remarkable darkneſs of this kind was that at our Saviour's paſſion, which laſted from noon till three of the clock in the afternoon.

From what hath been ſaid with regard to *Thales*, it appears, that there was, at that time, a method of predicting Eclipſes of the Sun, by ſome rules of art.

I ſay rules of art, becauſe, from ſome paſſages of Scripture, it ſeems as if ſolar Eclipſes had been predicted without them before this. For *Iſaiah*, who prophecied in the reign of *Uzziah*, or about the year before Chriſt 760, in a prophecy againſt *Babylon* †, foretells, that "*the Sun* "*ſhall be darkened in his going forth, and the Moon ſhall not cauſe her* "*light to ſhine.*"

* Georg. i. v. 467. † Chap. xiii. ver. 10.

And

And *Amos*, his contemporary, ſays *, *It ſhall come to paſs in that day, "ſaith the Lord God, that I will cauſe the Sun to go down at noon, and I "will* darken *the Earth in the clear day.*"

Ezekiel, who lived at the time when *Jeruſalem* was taken by the *Chaldeans* under *Nebuchadnezzar*, about the year before Chriſt 599, ſeems to ſpeak of a ſolar Eclipſe that was to be very remarkable at *Daphne*, or *Peluſium*, when he ſays †, "*At* Tehaphnehes *alſo the day ſhall be* dark-"ened, *when I (God) ſhall break there the yokes of* Egypt."

And again, ſpeaking of the conqueſt of *Egypt* by the *Chaldeans* ‡, he ſays, "*I (God) will cover the Sun with a Cloud, and the Moon ſhall not "give her light.*"

Eclipſes of the Moon are, in theſe three paſſages, joined with Eclipſes of the Sun, for reaſons to be mentioned hereafter.

The word ענן *Anan*, here rendered a Cloud, ſignifies any obſtacle in general. This is the rather to be obſerved at preſent, as there will be occaſion for the remark in what is to follow ſome time hence.

The only thing that ſeems capable of being objected to this, is, that in Scripture *darkneſs* is ſometimes put as emblematical, or repreſentative of great diſtreſs and affliction: as when the day of the Lord is deſcribed § to be "*a day of trouble and diſtreſs, a day of waſteneſs and deſolation, a day "of* darkneſs *and* gloomineſs, *a day of* clouds *and* thick darkneſs."

The ſame image is likewiſe in *Joel* ‖, and in other places.

Nor is this figure unknown to other eaſtern writers. Thus in the *Antholog. Veterum*, publiſhed at the end of *Erpenius*'s Grammar, by *Schultens* ¶,

فلما رايت الصبر قد حبل لونه
وان كان يوما ذا كواكب مظلما

At quum videremus patientiam evictam
Diemq; uſq; eo, ut ſtellæ apparuerint, obſcuratum.

Where likewiſe ſee the comment.

But there ſeems to be a great difference between a general deſcription of darkneſs, and a darkneſs befalling the bodies of the Sun and Moon, at certain places of the Earth in particular. Add to which, that theſe places were ſuch as, in thoſe days, were the moſt noted for obſerving what paſſed in the Heavens.

But as theſe predictions were made by means of ſupernatural communications, the queſtion with which we are concerned is, by what rule

* Chap. viii. ver. 9. † Chap. xxx. ver. 18. ‡ Chap. xxxii. ver. 7.
§ Zeph. chap. i. ver. 15. ‖ Chap. ii. ver. 2. ¶ Page 518.

of

of art was *Thales* enabled to foretel an Eclipſe of the Sun to the *Ionians*? It doth not appear that he had any aſtronomical tables; for there is no room to ſuppoſe that there were any in times much later than his. It is moſt probable, therefore, it was by means of

THE CHALDEAN SAROS,

or, as it is now more commonly known by the term of,

THE PLINIAN PERIOD,

from *Pliny*, the firſt author that mentions it. It is a period conſiſting of 223 lunations, and was much eſteemed by the late excellent Dr. *Halley*.

"For obſerving (he ſays himſelf) the period of lunar inequalities, "which is performed in eighteen years and eleven days, or 223 luna- "tions, it is found that the returns of Eclipſes, and other phenomena of "the Moon's motion, are very regularly performed; ſo that whatever "error is found in a former period, the ſame is repeated again in a ſecond, "under the like circumſtances of the ſame diſtance of the Moon from "the Sun and Apogæon."

And from this principle it was, that from an Eclipſe of the Sun, obſerved at *London* and *Dantzick June* the 22d, 1666, he was enabled, he ſays, to predict another eighteen years afterwards, or *July* the 2d, 1684, with an exactneſs little inferior to the obſervation itſelf at the time. For,

By prediction,	The beginning was to be at *London*, at - - -	$2^h\ 10'$
	The end - - - - - at - - -	$4^h\ 28'$
By obſervation,	The beginning was at *London*, - at - - -	$2^h\ 10'$
	The end - - - - - at - - -	$4^h\ 27'$

Though this was a preciſion greater than we have any reaſon to think *Thales* was capable of, yet that this period of eighteen years, in which Eclipſes of the Sun and Moon return in order again, was, in ſome rude manner at leaſt, known to him, may be readily allowed.

It was certainly known to *Meton* at the time of the *Peloponneſian* war, or the year before Chriſt 431, and is the ſame that hath been ſince called, from him, the METONIC CYCLE.

It is this likewiſe that ſeems to be meant, when *Adonis*, or the Sun, is ſtiled in *Theocritus* *,

Οκλωκαιδεκέτης ἢ Εννεακαιδεκ' ὁ Γαμβρός.

* Idyl. xv.

The

The conjunction of the Sun and Moon being repreſented, in the mythological language, as a marriage.

But what is more to our preſent purpoſe, it was, probably, by means of this period that *Anaxagoras* afterwards was enabled, as it ſeems, to foretell the great ſolar Eclipſe, mentioned by *Thucydides* * to have happened in the firſt year of the *Peloponneſian* war, and not the fall of a ſtone into the *Ægoſpotamus*, as the ancients abſurdly ſuppoſed.

An Example of the Method whereby he might do this, will ſufficiently explain the nature of the Chaldean Saros, or Plinian Period.

In the firſt place, then, it muſt be obſerved, that the Chaldee word שרא *Sara* ſignifies nothing more than *initium*; and therefore it may be applied to the beginning of any period whatever in general, and if ſo, to a period of Eclipſes in particular.

The next remark may be, that this period is now more accurately known than it was by *Thales*, *Anaxagoras*, or *Meton*, and that it conſiſts of eighteen years ten days ſeven hours forty-three minutes and fifteen ſeconds, when there are five leap-years in the period.

But when there are only four leap-years in the period, it then conſiſts of eighteen years eleven days ſeven hours forty-three minutes and fifteen ſeconds.

Anaxagoras is ſuppoſed to have begun teaching philoſophy at *Athens* the year before Chriſt 480; and five years before that the Sun was eclipſed *July* the firſt at ſeven hours and one minute, and the year after was a leap-year; therefore in the two next ſucceeding periods there will be only found four leap-years, and in the third period will be five leap-years. And hence we may form the following table of ſolar Eclipſes.

In the year before Chriſt 485 ⊙ eclipſed *July*				1d	07h	01′ 00″
-18	-	-	+	11d	07h	43′ 15″
467 ⊙ eclipſed *July*				12d	14h	44′ 15″
-18	-	-	+	11d	07h	43′ 15″
449 ⊙ eclipſed *July*				23d	22h	27′ 30″
-18	-	-	+	10d	07h	43′ 15″
431 ⊙ eclipſed *Aug.*				03d	06h	10′ 45″
The Sun, therefore, by this method, was eclipſed, in the year before Chriſt 431, in *Auguſt*, at - -				03d	06h	10′ 45″
And by Dr. *Halley*'s tables, the mean time of this Eclipſe was at - - - -				03d	04h	54′ 40″
Whence we find the difference was only - -				00d	01h	16′ 05″

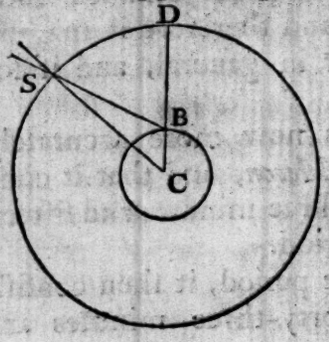
* Page 115, Edit. Waſſ.

Not

Not long after *Thales*, laſt ſpoken of, lived *Pythagoras*, ſaid to have been the inventor of ſeveral propoſitions that now make part of the firſt book of *Euclid*, particularly that very uſeful and elegant one, the 47th.

He is ſaid to have invented another propoſition, very uſeful in Aſtronomy (the 32d) in which it is proved, that if one ſide of a Triangle be produced, the outward Angle is equal to both the inward and oppoſite Angles together, and that the three inward Angles of a Triangle are equal to two right Angles.

By this propoſition we are enabled to find the difference between the true and apparent place of any Star, call'd its *Diurnal Parallax*.



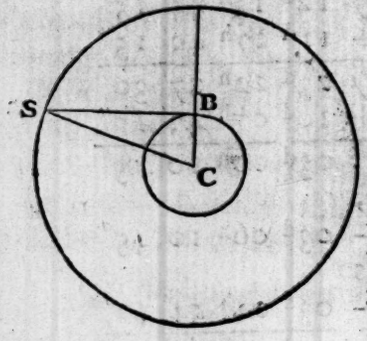
Let C be the center of the Earth, B the place of the obſerver on its ſurface, D the vertex of that place in the Heavens, S a Star, and the Angle D B S the diſtance of that Star from the Vertex, known by obſervation. Let the true diſtance of the Star from the Vertex, known by computation, be the Angle DCS; then, ſince by the propoſition above cited, the Angle DBS = BSC + BCS, it will be DBS − BCS = BSC, the Parallax required.

C O R O L. I.

Hence it appears, that the diurnal Parallax of any Star, is the Angle under which the ſemidiameter of the Earth would appear to an eye placed in that Star.

C O R O L. II.

It appears likewiſe that this Parallax will be greateſt when the Angle SBC is a right Angle, and then BSC is called the *Horizontal Parallax*.

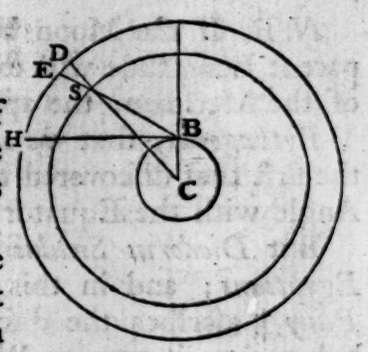


C O R O L. III.

It follows likewiſe that if the Angle BSC becomes = o, or vaniſhes, the Star will be at an infinite diſtance; and on the other hand, if the Star be at an infinite diſtance, then the Angle BSC will be = o. And for this reaſon it is, that the fixed Stars, being at an immenſe diſtance from the Earth, are ſubject to no diurnal Parallax at all. But the Moon, being neareſt to the Earth of all the Planets, hath conſequently the greateſt Parallax.

COROL.

COROL. IV.



Hence likewiſe it appears, that by means of this Parallax, the height of any body above the Horizon is diminiſhed, *i. e.* its apparent place is lower than its true place.

For S, when viewed from the center of the Earth C, will be ſeen among the fixed Stars at D. But when ſeen from the ſurface of the Earth at B, it will be ſeen at E, *i. e.* nearer to the Horizon BH.

From hence likewiſe we have the following

PROPOSITION VIII.

By means of this Parallax the Longitude, Latitude, Declination, and right Aſcenſion of the Moon become different from the true ones.

And this gives the following

PROBLEM.

The Latitude of any place, the places of the Sun and Moon, and the hour, being given, to ſhew this upon the Globe.

Rectify the Globe for the Latitude of the place, the Sun's place, and the Zenith. Find the Moon's place by an Ephemeris, or let it be ſuppoſed to be otherwiſe known; there ſtick a ſmall black patch; turn the Globe about its axis, till the hour-index points to the given hour; lay the Quadrant of Altitude over the black patch, and that will ſhew the Moon's true height above the Horizon. From the Pole of the Ecliptic lay a fine thread over the black patch; that will cut the Ecliptic in the Moon's true Longitude, and at the ſame time ſhew her true Latitude.

A little below this black patch, and near the edge of the Quadrant of Altitude, ſtick another ſmall black patch; that will ſhew the Moon's apparent height above the Horizon cauſed by the Parallax. A thread drawn from the Pole of the Ecliptic over this black patch, will cut the Ecliptic in the point of the Moon's apparent Longitude, and will, at the ſame time, ſhew her apparent Latitude.

In the ſame manner, a thread drawn from the Pole of the Equator, and laid over theſe black patches, will ſhew the Moon's true and apparent right aſcenſions and declinations.

N. B. If the Moon be on the eaſtern ſide of the Meridian, the apparent Longitude will exceed the true. But if the Moon be to the Weſt of the Meridian, the apparent Longitude will be leſs than the true.

Pythagoras, that we are now ſpeaking of, is ſaid by ſome to have been the firſt that diſcovered the obliquity of the Ecliptic, or that it makes an Angle with the Equator.

But *Diodorus Siculus* ſays *, that *Oenopides Chius* learned it of the *Egyptians*; and in this he is followed by *Plutarch* and *Stobæus*. But *Pliny* ‡ aſcribes the diſcovery to *Anaximander* the *Mileſian*. Whoever it belongs to, it was, as *Pliny* juſtly ſtiles it, *rerum fores aperuiſſe*.

Pythagoras is ſaid to have firſt diſcovered that *Heſperus* and *Phoſphorus* were one and the ſame Star. From the name *Phoſphorus*, it ſeems as if this is the ſame Star that is called הילל בן שחר *Helal-ben-ſhahar* †, or *Helal ſon of the morning*; a name given it on account of its remarkable brightneſs. It is the ſame with the Planet *Venus*.

If ſo, this is the firſt mention of any Planet that occurs in any author whatever now extant. This was about the year before Chriſt 710.

And here we may take occaſion to introduce the following

PROBLEM.

To ſhew by the Globe in what poſition *Venus* is a morning, or evening Star.

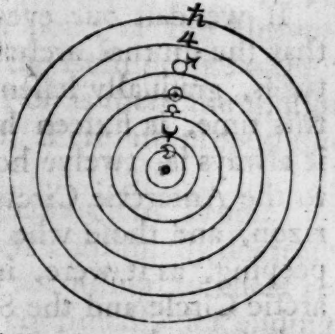
Rectify the Globe for the Latitude of the place, and the Sun's place; find the place of *Venus* by an Ephemeris, and having found the ſame on the Globe, ſtick there a ſmall black patch, as above directed; bring the Sun's place to the edge of the eaſtern Horizon. If *Venus* is in antecedence of the Sun, according to the order of the Sign; that is, *e. g.* in *Taurus* when the Sun is in *Gemini*, ſhe will riſe before the Sun, and in that poſition will be a *morning Star*.

But if *Venus* is in conſequence of the Sun, according to the order of Signs; that is, *e. g.* in *Gemini* when the Sun is in *Taurus*, ſhe will ſet after the Sun, and in that poſition ſhe will be an *evening Star*.

Though *Pythagoras* is commonly ſuppoſed to be the author of the preſent ſyſtem, called the *Pythagorean*, yet, from *Cenſorinus*, it appears, that his ſyſtem was this.

* Page 88. ‡ Nat. Hiſt. lib. ii. cap. 8. † Iſaiah xiv.

He



He ſuppoſed the *Earth* in the middle, then he placed the *Moon*, next after her *Mercury*, then *Venus*, then the *Sun*, then *Mars*, then *Jupiter*, and laſt of all *Saturn*.

It is moſt probable, therefore, that the preſent Pythagorean ſyſtem obtained that name, not from *Pythagoras* himſelf, but becauſe it grew up among the diſciples and followers of that Philoſopher.

Having ſeen by whom, and at what time, the obliquity of the Ecliptic was diſcovered; as the ſame obliquity is the cauſe of the variety of ſeaſons, we have the following

PROBLEM.

To explain by the Globe, in general, the alteration of ſeaſons, or the length of the days and nights, made, in all places of the World, by the Sun's apparent annual motion in the Ecliptic.

Let the Sun be ſuppoſed to be in the firſt point of *Cancer*, which now happens *June* the 21ſt, N. S. that point being brought to the Meridian, will ſhew the Sun's declination to be twenty-three degrees and a half North. Rectify the Globe for this Latitude, and, for the better illuſtration of the Problem, let the firſt Meridian on the Globe be brought under the braſs Meridian. The Globe being in this poſition, you will ſee, at one view, the length of the days in all Latitudes, by counting the number of hours contained between the two extreme Meridians cutting any particular Parallel you pitch upon in the eaſtern and weſtern part of the Horizon. One hour, as was ſaid before, is equivalent to fifteen degrees.

You may then obſerve, that the lower part of the Arctic Circle juſt touches the Horizon; and conſequently, all the people who live in that Latitude have the Sun above their Horizon for the ſpace of twenty-four hours, without ſetting; only when he is in the lower part of the Meridian (which they would call twelve o'clock at night) he juſt touches the Horizon.

To all thoſe who live between the Arctic Circle and the Pole, the Sun doth not ſet; and his height above the Horizon, when he is in the lower part of the Meridian, is equal to their diſtance from the Arctic Circle; thus, *e. g.* thoſe that live in the eightieth Parallel have the Sun, when he is loweſt at this time, thirteen degrees and a half high.

If we caſt our eyes ſouthward, towards the Equator, we ſhall find, that the diurnal arches, or the length of the days, in the ſeveral Latitudes, gradually leſſen. The diurnal arch in the Parallel of *London*, at this time, is ſixteen hours and a half: that of the Equator will be, as it always is, twelve hours; and ſo continually leſs and leſs, till we come to the Antarctic Circle; the upper part of which juſt touches the Horizon, and thoſe who live in this Latitude have juſt one ſight of the Sun, peeping, as it were, in the Horizon; and all the ſpace between the Antarctic Circle and the South Pole lies in total darkneſs.

If from this poſition we gradually move the Meridian of the Globe, according to the progreſſive alterations made in the Sun's declination, by his motion in the Ecliptic, we ſhall find the diurnal arches of all thoſe Parallels that are on the northern ſide of the Equator continually decreaſe, and thoſe on the ſouthern ſide continually increaſe, in the ſame manner as the days in thoſe places ſhorten and lengthen.

Let us again obſerve the Globe, when the Sun is got within ten degrees of the Equinoctial; then the lower part of the eightieth Parallel of North Latitude will juſt touch the Horizon, and all the ſpace between this and the Pole falls within the illuminated Hemiſphere; but all thoſe Parallels that lie between this and the Arctic Circle, which before were wholly above the Horizon, do now interſect it, and the Sun appears to them to riſe and ſet.

From hence to the Equator we ſhall find that the days have gradually ſhortened; and that from the Equator ſouthward they have gradually lengthened, until we come to the eightieth Parallel of South Latitude. The upper part of this will now juſt touch the Horizon, and all places between this and the South Pole will be in total darkneſs. All thoſe Parallels between this and the Antarctic Circle, which before were wholly below the Horizon, are now partly above it; and the length of the days there will be exactly equal to the length of the nights, in the ſame Latitude, in the other Hemiſphere. This likewiſe holds univerſally, that the length of the day in one Latitude North, is exactly equal to the length of the night in the ſame Latitude South, and *vice verſa*.

Let us again follow the motion of the Sun, until he has got into the Equinoctial, and take a view of the Globe in this poſition.

Now all the Parallels of Latitude are cut into two equal parts by the Horizon, and conſequently the days and nights are of equal lengths, *viz.* twelve hours each, in all places of the world, the Sun riſing and ſetting at ſix o'clock, excepting under the two Poles, which now lie exactly in the Horizon.

Here

Here the Sun ſeems to ſtand ſtill in the ſame point of the Heavens for ſome time, until by degrees, by his motion in the Ecliptic, he aſcends higher to one Pole, and diſappears to the other. For as there the motion of the Earth round her axis cannot be obſerved, there are properly no days and nights under the Poles.

If we follow the motion of the Sun towards the ſouthern Tropic, we ſhall ſee the diurnal arches of the northern Parallels continually decreaſe, and the ſouthern increaſe, in the ſame proportion, according to their reſpective Latitudes. The North Pole will be found continually deſcending, and the South Pole continually aſcending above the Horizon, until the Sun arrives at ♑.

Then all the ſpace within the Antarctic Circle is above the Horizon; while all the ſpace between the Arctic Circle and the North Pole is in total darkneſs: and we ſhall find all other circumſtances quite the reverſe to what they were when the Sun was in ♋, the nights now, all over the world, being of the ſame length that the days were of before.

We are now got to the extremity of the Sun's declination; and if we follow him through the other half of the Ecliptic, and rectify the Globe accordingly, we ſhall find the ſeaſons return in their order, until at length we bring the Globe into its firſt poſition.

This age of *Pythagoras* reminds us, not improperly, to add ſomething with relation to

HOURS.

The firſt time that the word HOUR, for a particle of the day, occurs, is in the book of *Daniel* *, under the reign of *Nebuchadnezzar*, about the year before Chriſt 600. This method of dividing the day into hours, therefore, probably began among the *Babylonians*, who communicated it to other people. *Herodotus* expreſly ſays †, that from them the *Greeks* learned the uſe of the *Pole, the Gnomon, and the diviſion of the day into twelve parts.*

The firſt of theſe was an inſtrument contrived to ſhew the time of the day; as the ſecond, by ſhewing the different lengths of the ſhadows at noon, pointed out the times of the Solſtices and Equinoxes, and conſequently the length of the tropical year.

How long they had been acquainted with this before the time of *Herodotus*, is uncertain; but, probably, it was learned from the *Babylonians* by

* Chap. iii. ver. 6. † Page 127.

Pherecydes,

Pherecydes, about the year before Chriſt 540, who ſet up a Pole, or Dial, in the iſland *Syra*, one of the *Cyclades*, as we are informed by *Diogenes Laertius*.

Anaximander is ſaid to have done the ſame thing, the firſt, at *Lacedæmon*. He died Olymp. lviii. 2. or the year before Chriſt 547. The *Lacedæmonians*, therefore, had the uſe of the Dial, and conſequently the knowledge of hours, ſomething earlier than the year before Chriſt 547. *Salmaſius*, in his *Plin. Exercit.* * ſays confidently, that the *Greeks* had not the uſe of the word *Hour* till long after the reign of *Alexander the Great*, which began, according to *Petavius*, the year before Chriſt 348. But in this he is miſtaken; for *Herodotus*, who wrote his Hiſtory about the year before Chriſt 431, uſeth the word Ὥρα for a particle of the day †.

The *Jews* ſeem to have been acquainted with the invention earlier than this, or in the reign of *Ahaz*; for we read of his Dial. He ended his reign, according to *Petavius*, the year before Chriſt 727; and therefore the *Jews* muſt have had the knowledge of the Dial near 200 years before the *Lacedæmonians*.

But this, perhaps, was only a curioſity, erected by that prince in his garden, as he ſeems to have been fond of exotic arts; and is no proof that Dials, or hours which were marked on them, were *commonly* known among the *Jews* ſo early as the reign of *Ahaz*. We certainly find no traces of any ſuch knowledge among them, in times much later than this.

What was the form of this Dial of *Ahaz*, is not known; but we may venture to form a conjecture, from what ſeems to have been the practice among the *Greeks*, who, as was ſaid before, had all the knowledge of this kind from the *Babylonians*, and from whom, either *immediately*, or *mediately*, through the *Syrians* at *Damaſcus*, *Ahaz* borrowed the conſtruction of his inſtrument. This naturally, therefore, brings us to ſay ſomething on the form and nature of the

GREEK DIALS.

In the conſtruction of the firſt Dials among the *Greeks*, there ſeems to have been erected a Gnomon perpendicular to the Horizon, adapted ſo to the *Climate*, or *Latitude* of the place, that its longeſt ſhadow, at the time of the Equinox, was *twelve* feet.

This ſeems to be proved, in ſome ſort, from a paſſage in *Ariſtophanes's Concionatrices* ‡, where a perſon ſays,

* Page 663. † Page 529. Edit. Gronov. ‡ Page 547. Ed. Kuſt.

---- σοὶ

---------- σοὶ δὲ μελήσει,
Οταν ἡ ΔΕΚΑΠΟΥΝ τὸ ΣΤΟΙΧΕΙΟΝ, λιπαρῶς χωρεῖν ἐπὶ δεῖπνον

---------- *Tibi autem curæ erit,*
Quando fuerit decem pedum *elementum pinguè* (unctum) *ire ad cænam.*

That is, "when the letter of the alphabet denoted the ſhadow to be ten "feet long, it was time to think of dreſſing, and going to ſupper."

As the *Greeks*, therefore, ſupped at Sun-ſet, it is plain, that when the ſhadow was ten feet long, the Sun began to grow low.

But that the longeſt ſhadow on theſe ſorts of Dials were twelve feet, is evident, from this fragment of *Menander*, who flouriſhed about the time of *Alexander the Great*.

------- διαφέρει Χαιρεφῶντος οὗτος γρυ
Ανθρωπος ὅστις ἐστὶν, ὡς κληθεὶς ποτε
Εἰς Ἐφιάσιν, ΔΩΔΕΚΑΠΩΔΟΣ, ὄρθριος
Πρὸς τὴν Σελήνην ἔτρεχε, τὴν Σκιὰν ἰδὼν,
Ως ὑστερίζων, καὶ παρῆν ἅμ' ἡμέρᾳ *.

"*Chærephon* is exactly like a perſon, that, being invited to an enter-"tainment, ſhould get up betimes in the morning by moon-light, and "ſeeing the ſhadow twelve feet long, for fear of being too late, ſhould "come there by day-break."

This, though intended only to ridicule the paraſite, yet ſhews that thoſe who did not come to an entertainment till the ſhadow on the Dial was twelve feet long, were thought to come very late: for indeed there is no mention made in authors of any ſhadow longer than this.

And *Heſychius*, on the word ΔΩΔΕΚΑΠΟΔΟΣ, ſays, Οὕτως ἔλεγον, Ελλειπτικῶς ΣΤΟΙΧΕΙΟΥ ἢ ΣΚΙΑΣ, οὕτω γὰρ συνετίθεντο ἐπὶ Δεῖπνον ἥξειν, τῷ ΣΤΟΙΧΕΙΟΥ ὄντος ΔΩΔΕΚΑΠΟΔΟΣ, ὡς νῦν πρὸς ΩΡΑΣ φασί. "*Ita* "*dixerunt, ſubintellecto* elemento vel umbra. *Sic enim ad cænam conven-*"*turos pacti ſunt olim, exiſtente* elemento duodecim *pedes longo, ut nunc* "*ad horas ſit.*"

Beſides that the different lengths of the ſhadows on theſe ſorts of Dials were marked by *feet*, it appears alſo that the diviſions upon them were *twelve*, in order to mark the *twelve* Hours between Sun-riſe and Sun-ſet.

This appears from a Greek epigram, cited by *Salmaſius* in his *Exercit. Plin.* on *Solinus* †.

* Reliq. Edit. Le Clerc, p. 139.

† Page 634.

Ωράων

Ωραων σκοσιαζε σοφον Σημαινορα Χαλκον
Αυτης εκ ΜΟΝΑΔΟΣ μεχρι ΔΥΩΔΕΚΑΔΟΣ.

From *one* to *twelve*, as Hours ſucceſſive paſs,
Mark their ſlow journey on the letter'd braſs.

As *theſe Hours* depend upon the length of the day, which is different at different ſeaſons of the year, it is plain that they will not always be of the ſame length, but longer in Summer, and ſhorter in Winter. But the difference in ſmall Latitudes will not be ſo conſiderable as in theſe countries that lie farther North.

Theſe hours ſeem to be the ſame with thoſe commonly called the *Babylonian Hours*, as being derived from that people; and ſometimes *Jewiſh*, as being the form made uſe of in that country. Though ſome diſtinguiſh the *Babylonian* hours from the *Jewiſh*.

The hours mentioned in the New Teſtament, muſt be underſtood as meant of theſe hours.

The hours in uſe amongſt us, are equal, or equinoctial hours. From whence we ſhall have the following

PROBLEM.

The Latitude of the place, the Sun's place, and the *Jewiſh*, or *Babylonian Hour*, being given, to find the time, according to our way of reckoning.

Rectify the Globe for the Latitude, and Sun's place, and find the number of hours the day conſiſts of, which ſuppoſe to be fourteen, and let the hour given be the third; then ſay

$14^h : 12^h :: 3^h : 2^h\ 34'\ 16''$

Time of Sun-riſe add - - -	$5^h\ 00''\ 00''$
Time required - - - - =	$7^h\ 34'\ 16''$

In the ſame manner may all the hours mentioned in the New Teſtament be reduced to our time.

Theſe diviſions, likewiſe, were marked with the ſeveral letters of the Greek alphabet, as is evident from another epigram, cited by the ſame author.

Εξ ΩΡΑΙ μόχθοις ἱκανωτάται αἳ δε μετ' αὐτὰς
Γράμμασι δεικνυμέναι ΖΗΘΙ λέγυσι Βρότοις.

But

But the force of this epigram depending on the letters of the Greek alphabet, Z, H, Θ, I, and their meaning, as a word, makes it impoſſible to tranſlate it into any other language.

DIAL OF AHAZ.

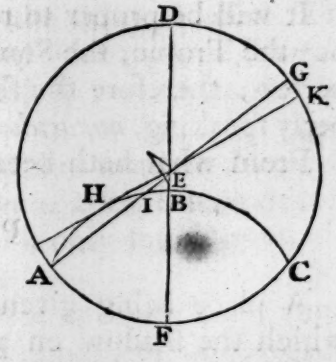
From what hath been ſaid, we may now not only form ſome kind of gueſs at the nature of the Dial of *Ahaz*, but likewiſe perceive the reaſon of its name, מעלות *Maaloth*.

For the Hebrew verb עלה *Alah*, anſwers to the Greek verb ΣΤΕΙΧΩ; and therefore the Hebrew ſubſtantive מעלות *Maaloth* will correſpond with the Greek ΣΤΟΙΧΕΙΑ, which ſignify the elementary letters of the alphabet, with which, it ſeems, the Hebrew or Babylonian Dials were marked, as well as the Greek.

Having, in this manner, diſcovered what was, probably, the form of *Ahaz*'s Dial, it may be entertaining, perhaps, to obſerve, that in ſome Latitudes, and at ſome times of the year, the ſhadow *may go back* on ſuch a Dial as this, *without a miracle*.

For in places within the Torrid Zone, while the Sun deſcribes, by his apparent diurnal motion, a parallel between that place and the Tropic neareſt to it, the ſhadow will go back once in the *morning*, and once in the *afternoon*.

EXAMPLE.



Let there be taken a place whoſe Latitude is leſs than 23° 29′, and let there be erected there a *Gnomon*, as E, on the horizontal plane ADCF, and let DF be the Meridian Line.

Let the Sun be riſing at A, and ſhine upon the Gnomon at E, then the direction of the ſhadow will be the line AEG.

Let ABC be the parallel deſcribed by the Sun, when his declination exceeds the Latitude of the place. When the Sun, by his apparent diurnal motion, comes to H, the direction of the ſhadow will be the line HEK, and the ſhadow will appear to have gone from G to K.

Let the Sun now proceed in his diurnal motion to I, and then the direction of the ſhadow will be IEG, the ſame that it was when the Sun was riſing at A, and the ſhadow will have *gone back* from K to G.

The line HK, it is plain, is a Tangent to the Sun's parallel ABC; and therefore what was ſaid of the points A and I, will hold good of any other two points that are equidiſtant from the point H.

What hath been ſaid of the points A, H, and I, before *noon*, will likewiſe hold good of three ſimilar points in the *afternoon*.

BY THE GLOBE.

Take a place, for example, whoſe Latitude is 15 deg. Rectify the Globe for that Latitude, and fix the Quadrant of Altitude in the Zenith.

Let the Sun's place be the beginning of *Cancer*. Bring the beginning of *Cancer* to the Meridian, and fix the hour-index to twelve. Bring that point to the edge of the eaſtern Horizon, and turn the Quadrant of Altitude till it cuts the Horizon and that point together. The hour-index will ſhew the time of Sun-riſing, and the Quadrant of Altitude will ſhew the Sun's azimuth at that time, and the direction of the Sun's rays on the Dial.

But the Quadrant of Altitude will likewiſe cut the Sun's parallel in another point above the Horizon, and conſequently ſhew that the Sun will come that morning into the ſame azimuth again; when the direction of the Sun's rays on the Dial will be the ſame as before.

Keeping the Globe fixed, turn the Quadrant of Altitude till it touches the Sun's parallel, and the motion of the Quadrant will ſhew the direction of the Sun's rays *forward* and *backward*.

It will be proper to remark in this place, that as *Jeruſalem* lies without the Tropic, the Sun never deſcribes a parallel to the northward of its vertex; therefore the ſhadow going back on the Dial of *Ahaz*, was, properly ſpeaking, *miraculous*, and not effected in the manner above related.

From what hath been ſaid, we may form the following

PROBLEM.

A place being given in the Torrid Zone, and one of thoſe days on which the ſhadow on a Dial there goes back, it is required to find the Sun's altitude and azimuth, and the hour when it will do ſo.

Elevate the Globe for the Latitude of the place, and fix the Quadrant of Altitude in the Zenith.

The day of the month being given, the Sun's place in the Ecliptic will be given on the wooden Horizon. Bring the Sun's place, juſt found, to the braſs Meridian, and fix the hour-index to twelve o'clock at noon.

Turn

Turn the Globe, till the Sun's place comes to the edge of the eaſtern Horizon, and the hour-index will ſhew the time of Sun-riſing that day. Turn the Quadrant of Altitude, till it cuts the Horizon in the Sun's place, and that will ſhew the Sun's azimuth at riſing.

The day of the month being given, and the Sun's place, his declination for that day will be given, and conſequently the parallel deſcribed by him that day.

Keeping the Quadrant of Altitude fixed, obſerve the point in it where it cuts the Sun's parallel. Turn the Globe, till the Sun's place comes up to that point, and the hour-index will ſhew the time when the Sun will be in the ſame azimuth, as before, at riſing; and the Quadrant of Altitude will ſhew the Sun's altitude at the time.

As the ſhadow hath now gone backward, turn the Globe, and the Quadrant of Altitude, till the Sun's place touches it: the hour-index will ſhew the time when the ſhadow began to go backwards, and the Quadrant of Altitude will ſhew the Sun's altitude and azimuth at the time, which was the thing required.

After what hath been ſaid on this Dial of *Ahaz*, it may not be amiſs to take notice of an error that ſeems to have crept into the text of *Iſaiah*: for nothing is more liable to corruption, in all ancient authors, than numbers. *Hezekiah* is promiſed that his life ſhall be prolonged fifteen years, and, as a ſign of this he is farther promiſed that the ſhadow on the Dial of *Ahaz* ſhall go back ten degrees.

But in ſuch kinds of repreſentations as theſe there is always an exact correſpondence between the thing *ſignifying* and the thing *ſignified*. Thus in *Geneſis**, *ſeven fat cattle* denote *ſeven years* of plenty, and *ſeven lean cattle* denote *ſeven years* of famine. So likewiſe † *three branches*, and *three baſkets*, denote *three days*.

From this rule it will follow, that if the addition made to *Hezekiah*'s life was fifteen years, the ſhadow ſhould have gone back fifteen degrees. On the other hand, if the ſhadow was to go back only ten degrees, then ten years only were to be added to his life.

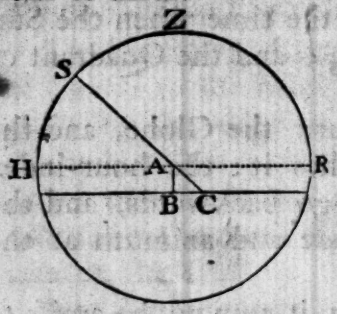
But this laſt was, moſt probably, the caſe: for as it doth not appear that the form of this Dial admitted of fifteen degrees, or diviſions, the ſhadow could not go back fifteen degrees. It, therefore, only went back ten degrees, and ten years only muſt have been added to *Hezekiah*'s life.

After what hath been ſaid on the form and nature of theſe Dials, as inſtruments for marking the hours of the day, it will be proper, like-

* Chap. xli. † Chap. xl.

wiſe, to conſider them in another capacity, and that is, as they were applied to the finding the Latitudes of places, or, which is the ſame thing, the diſtance of the Circle of *perpetual Apparation* of the fixed Stars from the Pole.

In order to which, the firſt thing to be obſerved, was, what proportion the length of the Gnomon bore to the length of the ſhadow at noon on the day of the Equinox. This, in different Latitudes, was different: at *Athens* (as we learn from *Hipparchus* in *Petav. Uranolog.* *) it was as four to three.



Therefore making AB, the height of the Gnomon, four feet, and BC the length of the ſhadow, = 3 feet = Radius, ſay, 3 : 4 : : Radius: to the Tangent of 53° 8′ = the height of the Equator; the complement of which will be 36° 52′ = the Latitude of the place, or the diſtance of the Circle of perpetual Apparition from the Pole.

Hipparchus, in the place above cited, makes it 37° but, according to Dr. *Halley*'s tables, the Latitude of *Athens* is 38° 5′.

This is ſufficient to ſhew the method, which is all that is intended. But ſince by theſe inſtruments, and ſuch kind of obſervations, the ancients determined the length of their days, and conſequently the breadth of their Climates, it will not be foreign to the purpoſe to introduce here the following

PROBLEM.

To find the Climates by the Globe.

A Climate is nothing more than a tract on the ſurface of the Earth, included between two ſuch Parallels of Latitude, that the length of the longeſt day in the one exceeds the length of the longeſt day in the other by half an hour.

Theſe Parallels are commonly marked on the terreſtrial Globe. Elevate the Globe for one of theſe Parallels, and take any place in it at pleaſure, and find the length of the longeſt day there. Elevate the Globe, till the length of the longeſt day in the next Parallel be found to exceed the length of the longeſt day in the former by half an hour; all that ſpace, upon the Earth's ſurface, included between the two Parallels, will be a Climate.

* Page 181.

N. B. What

N. B. What is here ſaid, is only to be underſtood of Climates lying between the Equator and the Polar Circles, which is ſufficient for underſtanding the ancients. Between the Polar Circles and the Poles the length of the longeſt day in one Parallel exceeds the length of the longeſt day in the next by a month. But theſe parts the ancients knew nothing of.

As the *Romans*, by conquering the *Greeks*, became acquainted with their arts, and afterwards made ſuch a figure in the World, we muſt not omit to add here a word or two on the

ROMAN DIALS AND DIALLING.

The firſt Dial ſet up at *Rome* is ſaid to have been erected by *Papirius Curſor* *. This was about A. V. C. 447, or the year before Chriſt 306.

But where this Dial was placed, is not agreed on. Some, as we are informed by *Cenſorinus* †, ſaid it was erected at the temple of *Quirinus*, others at the Capitol, others at the temple of *Diana*, on the *Aventine-Hill*.

But there was none erected in the Forum, according to *Cenſorinus* ‡, before that which was brought from *Sicily* by *Valerius*, about thirty years afterwards, or about the year before Chriſt 276.

This, however, being made for a town in *Sicily*, was found not to agree to the Latitude of *Rome*; therefore *L. Philippus*, in his cenſorſhip, cauſed another to be erected by it: but whether this anſwered the purpoſe better, is uncertain. However, not long after this, *P. Cornelius Naſica*, in his cenſorſhip, cauſed another inſtrument to be erected, for ſhewing the time of the day by *the running of water*, which, by a *catachreſis*, was likewiſe called, *ex conſuetudine noſcendi à ſole horas*, SOLARIUM §.

From a paſſage in *Plautus*, who flouriſhed about the year of *Rome* 535, or the year before Chriſt 218, it ſeems as if Dials had not been known at *Rome* long before that; and therefore when he ſays,

Itaque adeo jam oppletum eſt oppidum ſolariis,

it muſt be looked upon as an exaggeration, and in that place purely deſigned to raiſe a laugh.

It ſeems as if, in later times at leaſt, the men of fortune in *Rome* had ſervants whoſe buſineſs it was to tell the maſter the hour of the day. So *Juvenal*, in reckoning up the inconveniences of old age, adds,

* Plin. Nat. Hiſt. l. vii. c. 60. † De Die Nat. c. 23. ‡ Ibid. § Ibid.

---- *Clamore*

-------- Clamore opus eſt ut ſentiat auris
Quem dicat veniſſe puer, quot nunciat horas †.

The ſame thing likewiſe appears from *Martial*.

Horas quinque puer nondum tibi nunciat, & tu
Jam conviva mihi Cæciliane venis ‡.

As the *Romans* borrowed their method of dialling from the *Greeks*, and the *Greeks*, as was ſeen above, derived theirs from the *Babylonians*, we may eaſily conclude that the Roman Dials imitated the Greek and Babylonian forms.

The Roman day, therefore, was divided into twelve parts, between Sun-riſing and Sun-ſetting, like the Greek and Babylonian day; and that it was ſo, appears from *Juvenal* and *Martial*.

The *Jewiſh* day, as obſerved before, and as appears from *John* xi. 9. at the beginning of the Chriſtian æra, conſiſted of twelve hours; but whether in this the *Jews* imitated the *Babylonians* immediately, or borrowed the practice from the *Greeks*, or, being at that time a Roman province, conformed to the cuſtom of their conquerors in this reſpect, makes no difference at all.

After what hath been ſaid concerning the diviſion of the day, it naturally follows that we ſay ſomething with relation to the diviſion of the night into

WATCHES.

We find mention made of theſe as early as the time when the *Iſraelites* left *Egypt*, or the year before Chriſt 1531: ſo that we may conclude the practice was, at leaſt, as old as this in *Egypt*.

In what manner theſe watches were divided, and eſpecially in thoſe early times, is not very clear; perhaps it was by the running of water, or ſand, out of one veſſel into another.

Another method was, perhaps, by marking the progreſs of the fixed Stars, and afterwards the Conſtellations, as they roſe, culminated, or ſet. This may be gathered, in ſome ſort, from a paſſage in *Iſaiah* *, "Watchman, how much of the night? Watchman, how much of the night *is paſt?* The morning (ſays he) is coming, but it is yet night."

But it appears more clearly from the chorus in *Euripides*, which aſks

Whoſe is the watch? what Star now paſſes
The duſky noon of night?-------

† Sat. x. ver. 216. ‡ Lib. viii. epig. 67. * Chap. xxi. ver. 11, 12.

---- ſome

---------- ſome Conſtellations
Are ſet already; and the Pleiades
In eaſtern Skies appear. The Eagle flies
In Heaven's high ſummit †. ------

Whether the night was divided into more than three parts, or watches, at firſt, is not certain. But in after-times, particularly among the *Romans*, it was divided into four watches, as appears, among other inſtances, from this line of *Propertius* ‡,

Et jam quarta *canit venturam buccina lucem.*

From which ſame paſſage likewiſe it appears, that, amongſt them, the watches were diſtinguiſhed by ſound of trumpet.

And ſo, when *Pompey* determines to ſail away privately, without alarming *Cæſar*'s camp, he orders, in *Lucan*,

---------- *ne litora clamor*
Nauticus exagitet, neu buccina *dividat horas* §.

At the beginning of the Chriſtian æra, the night was divided into four watches among the *Jews*. For about the fourth watch, ſays St. *Mark* *, the diſciples ſaw their maſter walking towards them on the Sea of *Galilee*.

The ſame Evangeliſt, in another place †, expreſſeth the four diviſions of the night by *Even*, *Midnight*, *Cock-crowing*, and the *Morning*.

It may be obſerved, that ſome authors, as *Theocritus* ‡, ſpeak of *three cock-crowings*; and ſo our *Shakeſpear* doth.

------ the village cock
Hath *thrice* done ſalutation to the morn.

But it is the *ſecond cock-crowing* that is principally taken notice of by authors, and ſtiled emphatically *cock-crowing*.

Beſides this diviſion of the night into watches, it may be proper likewiſe to obſerve, that among the *Romans*, in the Auguſtan age at leaſt, the night was diſtinguiſhed into hours as well as the day, and probably began at *Sun-ſet*. Thus *Felix* orders the guard that was to carry *Paul* to *Cæſarea* §, to be ready at the *third* hour of the night.

Theſe hours, it is probable, were marked by the running of water, or ſand, out of one veſſel into another, as obſerved before of the watches, and would be of different lengths, at different ſeaſons of the year. But the

† Rheſus, ver. 527. ‡ Lib. iv. eleg. 4. § Pharſal. lib. ii. * Chap. vi. ver. 46.
† Chap. xiii. ver. 35. ‡ Idyl. xxiv. ver. 63. § Acts chap. xxiii. ver. 23.

time

time of the year being given, they will be reduced to our form of computation, in the ſame manner as was obſerved before concerning the day-hours.

It muſt not be omitted, in this place, to take notice, that princes, great officers of ſtate, and other principal perſons, had ſervants, whoſe employment it was to attend their *horary machines*, whatever they were, and to inform them of the time of night. And ſo *Joſephus* ſays, that "*Artaxerxes* enquired the hour of the night of thoſe whoſe buſineſs "it was to *inform him* ‖."

Soon after *Anaxagoras*, or about the year before Chriſt 470, according to ſome, was born

DEMOCRITUS,

ſtiled by *Seneca* * *ſubtiliſſimus antiquorum omnium*. He, if rightly repreſented by *Plutarch* ‡, was of the ſame opinion with *Anaxagoras* in relation to the body or ſubſtance of the Moon, *i. e.* that ſhe was a ſolid body, of a fiery nature, having on her ſurface plains, hills, and valleys.

But as *Anaxagoras* knew the nature of ſolar Eclipſes, he knew the Moon muſt be an opake body; therefore one part of this account cannot be true of *Anaxagoras*, nor of *Democritus*, if he was of the ſame opinion with him.

If *Democritus* thought the Moon was like our Earth, he might conclude, by way of analogy, that ſhe had hills and valleys as we have here. Since the invention of Teleſcopes, this is found to be matter of fact. In *Keil*'s Aſtronomy † there is given a method, whereby the hills in the Moon may be meaſured; and from thence it appears, that the hill called St. *Katherine*'s is about nine miles high, which is above three times as high as any hill upon Earth.

Democritus, according to *Plutarch* §, was of opinion, that the *milky way* was nothing more than a collection of ſmall Stars; and that Comets were only the coalition of *two* Stars. The firſt of theſe hath been confirmed ſince the invention of Teleſcopes, the laſt is probably not true.

For ſome of the *Pythagoreans*, as *Plutarch* tells us in the ſame place, thought a Comet was one of that ſort of Stars which appear only at certain periods of time; and the ſame, moſt likely, was the opinion of *Democritus*: for according to *Seneca*, as quoted above, he ſuſpected *pluras*

‖ Antiq. Jud. lib. xi. cap. 6. * Nat. Quæſt. l. vii. c. 8. ‡ De Placit. Philoſ. l. ii. c. 25.
† Page 107. § De Placit. Philoſ. l. iii. c. 1.

Stellas

Stellas esse quæ currant; that is, that there were other Stars besides the seven Planets that had a motion of their own.

I say, only a *motion of their own* in general: for in the time of *Democritus*, according to *Seneca*, the planetary motions were but little understood; *nondum comprehensis* quinque siderum *cursibus*.

PLATO AND EUDOXUS,

about the year before Christ 364, travelled into *Egypt*, and there learned from the priests that the year consisted of 365 days and a quarter, which before that time, according to *Strabo* ¶, was unknown to the *Greeks*.

These philosophers likewise are said to have first brought the *Greeks* acquainted with the motions of the Planets, that is, as it seems, taught them, in a rude manner, their order and periodical times.

Plutarch says, that *Plato* and the *Mathematicians* made the motions of the Sun, *Venus*, and *Mercury*, to be of equal swiftness *.

And here it may be properly enough observed, that *Venus* and *Mercury*, keeping always near the Sun, were the cause of great confusion, among the ancients, concerning the order in which they were to be placed.

We have spoke already of Constellations, and the antiquity of forming such Assemblages. That they were neither formed all at once, nor by any one people, is highly probable. As they are come down to us at present, they are the work of the *Greeks*, who borrowed them from abroad, and modelling them according to their own fancies, applied them to the *fabulous history* of their ancestors.

The first complete collection that we have of them, is that given us by *Aratus*.

But the Constellations described by him, are, according to *Hipparchus* †, nothing more than the Sphere of *Eudoxus*. So that the Sphere of the *Greeks*, as we there have it, was probably, if not formed, yet new-modelled, or, at least, had the finishing hand put to it by *Eudoxus*.

That the *Greeks* borrowed the first rudiments of their Astronomy from abroad, is owned in this remarkable passage in *Plato's Epinomis*. "The "first (says he) who observed these things was a *Barbarian*, who lived "in an ancient country, where, on account of the clearness of the "Summer season, they could first discover them. Such are *Egypt* and "*Syria*, where the Stars are clearly seen, there being neither rains nor

¶ Page 1160. * De Placit. Philos. l. ii. c. 15. † Petav. Uranolog. p. 173.

" clouds to hinder their ſight. And becauſe we are more remote from " this fine Summer weather than the *Barbarians*, we came later to the " knowledge of theſe Stars."

By the *Barbarians*, we ſee, he principally means the *Egyptians* and *Syrians*. Under the term *Syrians*, the *Greeks* comprehended the people properly called *Aſſyrians*; ſuch were the *Chaldeans*, and the *Arabians* bordering upon them, called in Scripture *Cuſh*, and by other writers Αἰθίοπες, *Ethiopians*. It is of theſe *Ethiopians*, and not of the *African*, that *Lucian* muſt be underſtood, when he tells us, that " the *Ethiopians* " firſt took notice of the heavenly motions; and by finding out the " cauſe of the lunations, diſcovered that the Moon had no proper light " of her own, but borrowed her light from the Sun."

Aratus, in deſcribing the Sphere of the *Greeks*, gives directions for finding each Conſtellation, by ſhewing its poſition in the Heavens with reſpect to ſome other near it, whoſe poſition is already known.

Beſides the fixed Stars, thus ranged into Conſtellations, he ſays there are five others, whoſe places cannot be found in the ſame manner with the reſt, becauſe they do not always preſerve the ſame relative diſtances from each other. Theſe are the Planets, which have a motion of their own, and therefore are continually changing their ſituation.

Nevertheleſs, by the Globe, and by the help of an Ephemeris, we may form the following

PROBLEM.

The day of the month being given, to find the places of all the Planets, their longitudes, latitudes, right aſcenſions and declinations, likewiſe the times of their riſing, ſetting, culminating, or coming to the Meridian at any place, or in any given Latitude.

Find by an Ephemeris the places of the Planets in the Ecliptic, with their Latitudes, if need be, and there ſtick ſmall black patches.

Rectify the Globe for the Latitude of the place, and the Sun's place, and then all the reſt will be found in the ſame manner as was taught with relation to the fixed Stars.

Contemporary with *Plato* and *Eudoxus*, before-mentioned, was

PHILOLAUS,

who aſſerted the *annual motion* of the *Earth* about the *Sun*. But by what obſervations, or arguments, he collected this, is uncertain.

Soon after *Philolaus*, but how ſoon is uncertain, lived

HICETAS,

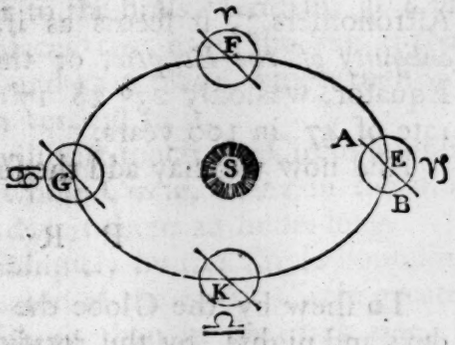
HICETAS,

a *Syracuſan*, who, according to *Tully* *, on the authority of *Theophraſtus*, aſſerted the *diurnal motion* of the *Earth* about her own axis. And this he did, perhaps, in order to avoid the difficulties ariſing from the common hypotheſis, which made the Heavens turn round the Earth, with a very rapid motion, in the ſpace of twenty-four hours.

" A very rapid motion, indeed! For if the Sun was to go round the " Earth in a day, he muſt travel at the rate of 300,000 miles in a mi- " nute, and upwards. But the fixed Stars being at leaſt 10,000 times " as far from us as the Sun, thoſe about the Equator muſt move 10,000 " times as quick †."

Theſe two determinations of *Philolaus* and *Hicetas*, are the baſis of all our modern Aſtronomy, which, therefore, it may be worth while to conſider a little more particularly. For by the annual motion of the Earth about the Sun, and the inclination of its axis to the plane of its orbit, are cauſed all the *varieties of the ſeaſons*; and to the rotation of the Earth about her axis, are owing all the *viciſſitudes of day and night*.

We have ſeen already in what manner may be explained by the Globe the variety of ſeaſons, ariſing from the Sun's annual motion in the Ecliptic. This motion is only the *apparent* motion of the Sun; the *true* motion is the *real* motion of the Earth, aſſerted, as we juſt now ſaw, if not diſcovered firſt, by *Philolaus*. In order then to correct ſuch erroneous apprehenſions as may ariſe in the mind from the uſe of a Globe, we muſt have recourſe to ſome ſuch figure as this.



Where S repreſents the Sun, E the Earth, AB the axis of the Earth, making, with the line of the Earth's annual motion round the Sun, an Angle of ſixty-ſix degrees and a half. At E this axis inclines towards the Sun; and therefore the Sun ſeen from the Earth, appears in the oppoſite point of the Heavens in *Cancer*; and now it is Summer.

The Earth advancing in its orbit, and keeping its axis parallel to itſelf, arrives at F, which is the *autumnal Equinox*.

* Acad. p. 228. † Ferguſ. Aſtron. p. 38.

Being arrived at G, and keeping its axis ſtill parallel to itſelf, it will decline from the Sun. Then the Sun will appear, in the appoſite part of the Heavens, at *Capricorn*; and now it will be Winter.

Laſtly, when the Earth arrives at K, the Sun will appear, in the oppoſite point of the Heavens, at *Aries*; and then it will be the *vernal Equinox*.

It was obſerved, ſome time ago, that the Angle of inclination of the Equator to the Ecliptic, was, by *Manilius* the Roman poet, made 24° but that now it is made only 23° 29′. Whether this is owing to the inaccuracy of ancient inſtruments and obſervers, or to any real change in the Angle itſelf, hath been made a doubt.

About the time of *Alexander the Great*, or the time we are now ſpeaking of, at *Marſeilles* in *France* lived

PYTHEAS,

who, according to *Cleomedes* *, on the day of the Summer Solſtice, took the Sun's meridian altitude there. The proportion of the Gnomon to the length of the ſhadow, was, according to *Hipparchus* †, that of 600 to 209, which is nearly the ſame that *Gaſſendus*, the *French* Aſtronomer, found it A. D. 1636.

As far, therefore, as theſe obſervations go, it appears, that between the times of *Pytheas* and *Gaſſendus*, that is, for about the ſpace of 1960 years, the obliquity of the Ecliptic had not been altered.

Yet by comparing together other obſervations, made ſince that time, and in other places, and with greater accuracy, according to the *French* Aſtronomers ‡, it ſeems as if, at the beginning of the year 1761, the *obliquity of the Ecliptic*, or the Angle made by the Ecliptic and the Equator, was only 23° 28′ 17″ and that this Angle really decreaſes at the rate of 47″ in 100 years.

And now we may add the following

PROBLEM.

To ſhew by the Globe the true cauſe of the different lengths of the days and nights, by the rotation of the Earth about her axis in twenty-four hours.

The Sun always illuminates one half of the Earth, or that Hemiſphere which is next towards him, while the other remains in darkneſs. There

* Lib. i. c. 7. † In Strab. p. 175. ‡ In the Connoiſance des Temps for 1761.

will,

will, therefore, be a Circle bounding *light* and *darkneſs*, or ſeparating the *illuminated* Hemiſphere from the *dark* one.

Bring the Poles of the Equator to lie on the wooden Horizon; and if with a ſtring you hang an ivory ball over the Equator, to repreſent the Sun, then the wooden Horizon will repreſent the Circle bounding light and darkneſs.

If you bring up any particular place to the Meridian, as *London*, you will ſee, at one view, all thoſe places where it is noon; and that place which lies directly under the ball, will have the Sun in its Vertex. If you ſet the Globe due North and South, then all thoſe places that lie on the the weſtern ſide of the wooden Horizon will be coming into the *illuminated* Hemiſphere, and conſequently will have the Sun riſing. On the the contrary, all thoſe places that lie on the edge of the eaſtern Horizon, will be going out of the illuminated Hemiſphere into the dark one, and conſequently will have the Sun ſetting.

The Circle bounding light and darkneſs, by paſſing through the Poles, will divide all the Circles of Latitude into two equal parts. One half will lie in the illuminated Hemiſphere, and the other half in the dark; and conſequently this ſhews that the days and nights are equal all over the World.

Let us now raiſe the North Pole to 23 degrees and a half, and bring the firſt point of *Cancer* into the Meridian. Over this hang the ivory ball as before. Turn the Globe about its axis from Weſt to Eaſt; then the Sun will appear to deſcribe the northern Tropic from Eaſt to Weſt for that day, and all places that lie in that parallel of Latitude will have the Sun that day vertical to them.

If you bring up any place in particular to the braſs Meridian, as *London*, you will ſee, as before, all thoſe places that have the Sun at that time riſing, ſetting, or in the Meridian, and that place which then lies directly under the ball, will have the Sun vertical to it.

The lower edge of the Arctic Circle will juſt touch the Circle bounding light and darkneſs; therefore the whole Circle, being in the illuminated Hemiſphere, will ſhew that the day is there 24 hours long.

As the Parallels of Latitude are cut obliquely by the Circle bounding light and darkneſs, and as from the Equator to the Arctic Circle greater portions are in the illuminated Hemiſphere than in the dark one, it ſhews that the days are longer than the nights; and the farther the Parallel lies from the Equator, the longer will be the day there, till, as we have ſeen, under the Arctic Circle there is no night at all. The Sun at their twelve o'clock at night, as it may be called for want of a better term,

term, will only just touch the Horizon in the North part of their Meridian.

In all other Parallels between the Arctic Circle and the Pole, the Sun will appear higher and higher, when under the northern Meridian, as the Parallel itself is wholly more and more within the illuminated Hemisphere, till at last, under the Pole itself, the Sun will not appear to describe any Circle at all, *i. e.* will seem to *stand still.*

The reverse of all this will happen in the Parallels between the Equator and the Antarctic Circle. For greater portions of them falling in the dark Hemisphere than in the illuminated one, shews that the days will be shorter than the nights, till we come to the Antarctic Circle itself. The upper point of this will only touch the Circle bounding light and darkness, and there consequently the Sun will just appear at twelve o'clock at noon, and immediately disappear again. The inhabitants lying between the Antarctic Circle and that Pole, if such there be, will have now no day at all.

If the Poles be brought to lie on the wooden Horizon again, every thing will be exactly the same as when they were in the same situation before. And if we elevate the South Pole 23 degrees and a half above the wooden Horizon, the upper edge of the Arctic Circle will then only touch the Circle bounding light and darkness, and the inhabitants lying between that Circle and the North Pole will now, in their turn, have no day at all.

PART

PART IV.

THE HISTORY OF ASTRONOMY, FROM ALEXANDER THE GREAT TO THE TIME OF PTOLEMY.

IT doth not appear that *Babylon* was, at all, a ſeat of learning under the *Syro-Macedon* princes, who ſucceeded *Alexander* in that part of his vaſt conqueſts.

The place we are now to look for the Sciences, is at *Alexandria* in *Egypt*, a town built by *Alexander*, and where *Ptolemy Lagus* * began to reign the year before Chriſt 321.

What obſervations were made by the *Egyptians*, before the *Greeks* came amongſt them, is uncertain. The few things which they are known to have done, have been taken notice of before.

But the firſt perſons among the *Greeks* that applied themſelves to the ſtudy of Aſtronomy after *Alexandria* was built, and became the ſeat of learning, as far as it is known, were

TIMOCHARIS AND ARISTYLLUS.

This was about the year before Chriſt 290. There are obſervations made by both of them, mentioned by *Ptolemy* in his *Syntaxis*.

* See Vaillant. Hiſt. Ptol.

In

In the year before Chriſt 283, *Timocharis* obſerved an appulſe of the Moon to the *Spica Virginis*; and the place of this Star then was in the ſecond degree of *Virgo*, according to his determination.

This laſt obſervation will be found hereafter, when we come to ſpeak of *Ptolemy*, of very great conſequence in Aſtronomy.

About the year before Chriſt 270 flouriſhed the Poet

ARATUS.

To him, as hath been already obſerved, we owe the firſt complete Sphere of the *Greeks*. It is ſaid by *Hipparchus* to be nothing more than the Sphere of *Eudoxus*, put into elegant Greek verſe. For he obſerves, that it hath all the ſame miſtakes exactly with the treatiſe of *Eudoxus*, which he is ſuppoſed to have verſified.

How much this author was admired by the ancients, appears from *Ovid*.

Cum Sole & Luna ſemper Aratus erit.

He is quoted likewiſe by St. *Paul*, in his admirable Speech at *Athens*.

From what he ſays under the Conſtellation *Draco*, it appears, that his Sphere was compoſed ſomewhere about Latitude thirty-eight degrees North: for he ſays,

Κάνη πυ Κεφαλὴ τῇ νήχεται ἤχι περ ἄκραι
Μισγονται Δύσιές τε καὶ Ἀντολαὶ ἀλλήλῃσι.

That is, the head of *Draco* there touched the Horizon, when under the northern part of the Meridian.

Move the Globe up and down in the notches, till the head of *Draco* be brought under the North Meridian to the edge of the Horizon; then the height of the Pole, and conſequently the Latitude of the place, will be found to be about 38 degrees.

And in the ſame manner may any other obſervations of the like kind, mentioned by ancient authors, be examined.

The firſt perſon that treated of the ſurface of the Earth, as divided into Zones, was, according to *Achilles Tatius* *, *Parmenides*. Some, he ſays, as *Polybius* and *Poſidonius*, divided the Torrid Zone into two parts, and ſo made ſix Zones. Others, as *Eratoſthenes*, with whom he agrees himſelf, made them only five. And this, indeed, appears to have been the moſt uſual diviſion; and no wonder, conſidering how great the authority of *Eratoſthenes* was.

* Petav. Uranolog. p. 157.

As

As the Frigid Zones were thought to be uninhabited, on account of the cold, ſo all the ſpace included between the Tropics, called the Torrid Zone, was looked upon as being ſo, by reaſon of the heat. But in this, according to *Achilles Tatius* *, the ancients were not agreed.

Eratoſthenes, about the year before Chriſt 276, and the *Greeks* under the *Ptolemies*, as we ſhall ſee, were acquainted with *Egypt* as far as *Syene*, and, probably, knew the country but little farther. But there they found the heats exceſſive; and concluded, perhaps, that they were greater the farther they went. But in this they were miſtaken: for places near the Tropics, as *Dampier* obſerves in his Voyages †, "are "generally more inclined to great heats, than places near the Equator. "This (adds he) is what I have experienced in many places, in ſuch "Latitudes, both in the *Eaſt* and *Weſt Indies*, that the hotteſt parts of "the World are thoſe near the Tropics, eſpecially three or four degrees "within them; ſenſibly hotter than under the Line itſelf."

To the making theſe heats the greater, the reflection of the Sun-beams from the burning Sands of *Africa* would very much contribute, and help the ancients to form concluſions, which experience now demonſtrates to be falſe.

The nature of theſe burning ſands is ſuch, that they appear, in a manner, perfectly *molten*, and at a diſtance have much the reſemblance of *water*. In the Arabic language they are called السراب *Al-ſerâb*, and are frequently mentioned by their writers ‡. They were known to Q. *Curtius* §, and are beautifully alluded to by *Iſaiah*, who calls them השרב *Haſharab* ‖.

About the year before Chriſt 264, flouriſhed the Philoſopher and Mathematician,

ARISTARCHUS SAMIUS.

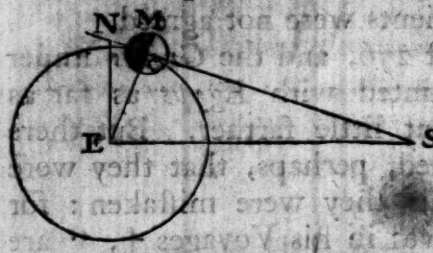
His works are all loſt, except a treatiſe, *De magnitudinibus & diſtantiis Solis & Lunæ*, preſerved by *Pappus* ¶, and publiſhed by Dr. *Wallis*.

By this it appears, that the Greek philoſophers had by this time began to apply Geometry to the Heavens. This, as far as appears, at leaſt, is more than was ever attempted either by the *Egyptians* or *Babylonians*.

He agreed with *Philolaus*, already mentioned, in aſſerting the annual motion of the Earth round the Sun.

* Ut ſup. p. 153. † Vol. ii. p. 33. ‡ See Hariri Conſeſ. vi. p. 170. Edit. Schult. Likewiſe Abul-Ol. Carm. ver. 4. & Gol. Adag. Arab. No. 55. in Erpenius's Grammar.
§ Lib. vii. ‖ Chap. xxxv. ver. 7. ¶ Mathemat. Collect. lib. vi.

He ſays the Moon, in her dichotomy, is diſtant from the Sun leſs than a Quadrant by one-thirtieth of a Quadrant, or three degrees; that is, that the Angle NEM is = 3°.



From whence, ſuppoſing S to be the Sun, E the Earth, C the center of the Moon at her dichotomy, E S the diſtance of the Sun from the Earth, and E C the diſtance of the Moon from the Earth, he proves *, that E S is to E C greater than eighteen to one, but leſs than twenty to one.

If, therefore, the diſtance of the Moon from the Earth can be obtained, the diſtance of the Sun from the Earth will, in rude numbers, be about nineteen times as much.

This method (though very ingenious) of finding the diſtance of the Sun from the Earth, yet wants much of that accuracy which is requiſite in ſo nice an affair.

I. For the Angle NEM, here ſuppoſed to be three degrees, is aſſumed much too big.

II. In the next place, it is extremely difficult to determine the true time of the Moon's dichotomy.

Under the firſt *Ptolemies*, in *Egypt*, about the year before Chriſt 252, reſided there

C O N O N.

He is ſaid by *Seneca* ‡, to have *collected all the Eclipſes obſerved by the* Egyptians.

This work, if it ever exiſted, is now loſt, and probably hath been ſo many years. *Ptolemy* ſeems to have known nothing of it, by his not mentioning it; for it is obſervable, that in all his work he takes no notice of any Eclipſe as ſet down by the *Egyptians*: either, therefore, they had obſerved none at all, or not obſerved them with exactneſs ſufficient for his purpoſe.

That *Conon* was an Aſtronomer, appears from this epigram of *Catullus*, where he ſpeaks of his forming the Conſtellation called *Berenice's Hair*.

Omnia qui magni diſpexit lumina mundi,
Qui Stellarum ortus comperit atque obitus.
Flammeus ut rapidi Solis nitor obſcuretur;

* Prop. vii. ‡ Nat. Quæſt. l. vii. c. 3.

Ut

Ut cedant Teris ſidera temporibus.
Idem, me, ille Conon *cæleſti lumine vidit,*
E Beriniceo *vertice Cæſariem.*

This *Conon* ſeems to be the ſame that is mentioned by *Virgil* *.

--------- Conon, *& quis fuit alter?*

He is likewiſe commended by *Archimedes* †, both as his friend, and likewiſe as an *excellent Mathematician.*

This, therefore, naturally leads us to the mention of

ARCHIMEDES,

whoſe character as a Geometrician is ſo well known to every one. But that he was likewiſe an Aſtronomer, appears from what is ſaid of him by *Livy* ‡ and *Solinus* §, as well as from his obſerving the Solſtices mentioned by *Ptolemy* in his *Syntaxis* ‖.

He is celebrated by *Cicero* ¶, for having made a Sphere, or kind of *Planetarium*, in which was repreſented the motion of the heavenly bodies. It is elegantly deſcribed, from report, or fancy, by *Claudian.*

But the thing of greateſt conſequence to be obſerved, becauſe of the utmoſt uſe in Aſtronomy for determining the diſtances of the Planets from the Sun, and from each other, is his finding the proportion between the circumference of a Circle and its diameter.

For he demonſtrated that the circumference of a Circle contains the diameter leſs than $3\frac{1}{7}$ or $3\frac{10}{70}$ and more than $3\frac{10}{71}$ times.

Put C for the circumference, and D for the diameter of a Circle. Then ſuppoſe $C = 3\frac{1}{7} \times D$, or $\frac{22}{7}$ D, it will be $7\,C = 22\,D$. Therefore,

$$C : D :: 22 : 7$$

But ſince the circumference C is greater than $\frac{22}{7}$ D, therefore 7 C will be greater than 22 D, and C : D greater than 22 : 7.

In the ſame manner it may be demonſtrated that it will be C : D leſs than 223 : 71.

And now, from theſe proportions, ſuppoſing the meaſure of a great Circle of the Earth, as given by *Eratoſthenes* hereafter, to be juſt, we ſhall have two diameters of the Earth.

* Eclog. iii. ver. 40. † Preface to his Book de Lineis Spiral. and his Book de Quadrat. Parab.
‡ Lib. xxiv. c. 34. § Lib. xi. ‖ Lib. iii. c. 2. ¶ De Nat. Deor. lib. ii. § 35.

HIPPARCHUS,

the prince of ancient Aſtronomers, flouriſhed about the year before Chriſt 160; and it is from his time only that we can properly fix the date of any thing that deſerves the name of Aſtronomy.

He ſeems to have collected all the Eclipſes that he could meet with, both of the Sun and Moon, obſerved by the *Babylonians*, and compared them with the times of the Athenian archons, and the months in the Athenian and Egyptian year. This ſeems to appear from the manner in which the Babyloniaan Eclipſes are quoted by *Ptolemy* in his *Syntaxis* ¶.

" For the firſt of the lunar Eclipſes brought from *Babylon*, he ſays, " and obſerved there, was in the archonſhip of *Phanoſtratus*, and in the " month *Poſeideon*. This, ſays *Ptolemy*, was An. Nab. 366, and as he " (*Hipparchus*) ſays, in the Egyptian way of reckoning, in the night " between the 26th and 27th of the month *Thoth*."

That the *Babylonians* ſhould mark their Eclipſes by the reigns of Athenian archons, whom, probably, they never heard of, or that they ſhould make uſe of Athenian and Egyptian months, is not probable. This muſt have been the work of *Hipparchus* himſelf, who was a *Greek*, and obſerved firſt at *Rhodes*, and afterwards at *Alexandria* in *Egypt*.

If to the year before Chriſt 160 we add 600 years, it will bring us to the year before Chriſt 760, a little before the beginning of the reign of *Nabonaſſar*; and beyond which he found no Eclipſes that would be of ſervice to him in ſtating the mean motions of the Sun and Moon.

Perhaps he made 600 years a Cycle, or Period of Eclipſes, like the Chaldean Saros, mentioned elſewhere, and called it the great year. Such a Period as this is mentioned by *Joſephus* *, and by no other author, as is obſerved by *Caſſini* †; ſo that where he had it, is not known. This Period is more accurately 557 years 21 days 18 hours 30 minutes 12 ſeconds. *Pliny* ‡, not being rightly informed, ſays, *Utriuſque ſideris curſum in ſexcentos annos præcinuiſſe, & menſes gentium, dieſque & horas, ac ſitus locorum, & vicos populorum complexus.* But the predicting Eclipſes in this manner doth not ſeem to have any uſe worth the pains, and eſpecially of ſo great an Aſtronomer, who could employ his time to better purpoſes.

Thoſe Eclipſes, therefore, which, as I remarked above, the Babylonian obſervers had ſet down, and noted by the years of the king's reign

¶ Page 105. * Antiq. lib. i. cap. 3. † De l'Orig. & Prog. de l'Aſtron. p. 4.
‡ Nat. Hiſt. lib. ii. cap. 12.

under

under whom they happened, he adjuſted and compared with the years of the Athenian archons, and the Athenian and Egyptian months. This was a preciſion of great uſe to the Greek Aſtronomers, whether ſettled at *Athens*, or *Alexandria*, at that time the capital of ſcience. The treatiſe compoſed by *Hipparchus* on this ſubject is loſt; but there ſeems to have been a *Syriac* tranſlation of it, if one may gueſs from the title, extant in the time of *Bar Hebræus*, about A. D. 1276.

Whenever we ſpoke of the Moon's motion before, we conſidered the plane of her orbit as coincident with the plane of the Sun's apparent annual motion in his own orbit, called the Ecliptic. But this is not ſtrictly the caſe: for the plane of the Moon's orbit interſects the plane of the Sun's orbit in two oppoſite points, called

THE NODES.

That point of the Sun's apparent orbit, where the Moon riſes above it towards the North Pole, is called the place of the

ASCENDING NODE.

And that point of the Sun's apparent orbit where the Moon deſcends below it towards the South Pole, is called the place of the

DESCENDING NODE.

And the line joining thoſe two points together, is called the

LINE OF THE NODES.

The poſition of the Moon's Nodes, at any time, may be found, in a groſs manner, by the Globes, thus.

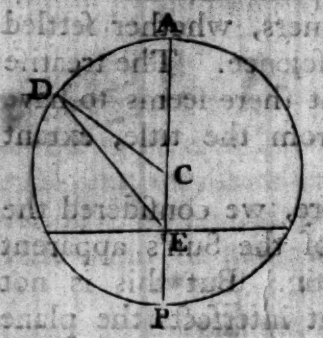
Find by an Ephemeris the Moon's place in the Ecliptic, with her Latitude, for three or four days together, and mark thoſe places with a black lead pencil, or by ſticking there ſmall black patches. Over thoſe places lay the Quadrant of Altitude, or a ſilken thread; and that point of the Ecliptic which is cut by it, will give the poſition of the Moon's Node.

If the Moon's Latitude be *increaſing*, it will be the *aſcending* Node: if her Latitude be *decreaſing*, it will be the *deſcending* Node.

This line of the Moon's Nodes is not always at reſt, *i. e.* doth not always point towards the ſame fixed Stars; and *Hipparchus* obſerved, the

firſt

first of any that we know of, that the Nodes themſelves have a ſlow motion *backwards*.



He obſerved likewiſe, that the Moon's motion in her own orbit, when ſeen from the Earth, was *not equable*, or that ſhe did not always deſcribe equal arches in equal times; but that her motion was ſwifteſt at P, her *Perigee*, and ſloweſt in A, her *Apogee*, ſuppoſing the place of the Earth at E, the center of the Moon's Cirole about the Earth at C; and therefore the eccentricity of her orbit to be EC.

He ſeems to have compoſed the firſt tables of the Sun and Moon's motions; but of thoſe only, for he did not attempt any for the motions of the Planets.

" It is ſo little a time (ſays *Ptolemy*) ſince we have had any obſerva-
" tions on the Planets committed to writing, in compariſon of the
" difficulty of the ſubject, that any predictions of their places, for any
" long time to come, are not much to be relied on. For which rea-
" ſon, and eſpecially having fewer obſervations of the ancients than of
" his own, I ſuppoſe, *Hipparchus*, a great lover of truth, though he
" undertook the buſineſs of the Sun and Moon, yet meddled not with
" the *five Planets*, as far, at leaſt, as I find, by any writings of his that
" have fallen into my hands *."

A new Star appearing in his time, gave him an occaſion of making a catalogue of the fixed Stars, as we are informed by *Pliny* †.

By comparing his own obſervations with thoſe made by *Timocharis* on the *Spica Virginis*, as we learn from *Ptolemy's Syntaxis* ‡, he firſt ſuſpected that ſlow motion of the fixed Stars from Weſt to Eaſt, whereby their Longitudes, Declinations, and right Aſcenſions, are altered, called now the *Præceſſion of the Equinox*.

From the Moon's falling into the ſhadow of the Earth at the time when ſhe is eclipſed, he contrived a method for finding the Parallax of the Sun.

This method may be ſeen in *Street's Aſtron. Carolin.* §, and in *Keil's Aſtron. Lect.* ||, and in many other authors. But we ſhall have occaſion to enlarge upon this more particularly hereafter. In the mean time, this brings us to the year before Chriſt 76, when, according to

* Syntax. lib. ix. cap. 2. † Nat. Hiſt. lib. i. cap. 26. ‡ Lib. vii. c. 1.
§ Page 60. || Lect. xxi.

Petaviut,

Petavius *, the first elements of Astronomy, at least that are come down to our hands, were wrote by

GEMINUS.

He adheres to the vulgar system, and places the Planets in the following order: *Saturn*, *Jupiter*, *Mars*, the *Sun*, *Venus*, *Mercury*, the *Moon*. So that in his time, the system of some *Pythagoreans*, who assigned the Sun a different position, was not, it seems, universally received.

From what *Geminus* says †, it seems as if the *Chaldeans* had stated the Moon's periodical revolution at twenty-seven days thirteen hours and twenty Minutes, and her synodical revolution at twenty-nine days twelve hours forty-three minutes and thirty-eight seconds.

They observed, likewise ‡, that the Moon did not always describe *equal arches* in *equal times*, but that she moved sometimes swifter, and sometimes slower. They, therefore, discovered her *mean motion* to be $13^{\circ}\ 10'\ 35''$ in a day.

It could have been wished that *Geminus* had told us what authors he had borrowed this from, or how early the *Chaldeans* had determined these several motions; for the term *Chaldeans* is ambiguous: it is applied not only to the *observers* at *Babylon* under the reigns of their own monarchs, but likewise to those under the reigns of the first *Medo-Persian* princes; and lastly, it is attributed to a set of strolling *fortune-tellers*, like our modern *Gypsies*. And so the word is used by *Juvenal* §.

Chaldæis sed major erit fiducia---------

But *Geminus* can only be understood as speaking of *Chaldeans* in the two former senses of the word.

What observations were made at *Babylon* between the time that it was taken by *Cyrus*, and afterwards by *Alexander*, doth not appear. It is certain there are no Eclipses recorded in *Ptolemy's Syntaxis*, as observed at that place, later than the reign of *Darius Hystaspes*. The reason may be, that the *Persian* princes never resided there, and, probably, gave no kind of encouragement to studies of this sort.

* Uranolog. p. 411. † Uranolog. p. 63. ‡ Ibid. p. 62.
§ Sat. vi. ver. 552.

The

The *Babylonians*, as we learn from *Herodotus* *, revolting from this *Darius*, were reduced by him, and treated in a very cruel manner; for upon taking their city by the treachery of *Zopyrus*, he crucified three thouſand inhabitants of the better ſort, took down their gates, and demoliſhed their walls.

With this ended the ſplendor of that ancient city, about the year before Chriſt 510.

From this time it ran to ruin. And though *Herodotus*, in leſs than 100 years afterwards, ſpeaks of the temple of *Belus* as yet ſtanding, *Diodorus Siculus*, who lived but juſt before the beginning of the Chriſtian æra, ſpeaks of it † as totally demoliſhed by age.

As to the town of *Babylon* itſelf, *Diodorus* ‡ repreſents it as very *thinly inhabited* in his time, the greateſt part of it within the walls being *turned into fields*. So that *Babylon* having been neglected under the *Perſian* kings, ſeems to have been more ſo under the *Syro-Macedon*. No wonder, therefore, we hear nothing of Aſtronomy, or aſtronomical obſervations, there after the reign of *Darius Hyſtaſpes*.

How, and in what manner, then, thoſe obſervations were preſerved that *Calliſthenes* is ſaid to have ſent *Ariſtotle* from thence, doth not appear.

* Page 220. † Page 98. ‡ In the ſame place.

PART

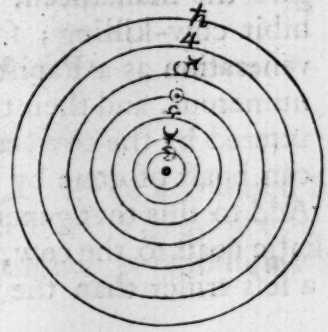
PART V.

THE HISTORY OF ASTRONOMY, FROM PTOLEMY TO TYCHO BRAHE.

WITHIN this period, however, we ſhall find that few or no improvements were made, either in Geography, or Aſtronomy; the few Philoſophers of this time confined themſelves to the ſtudy of *Ptolemy*'s works alone. This period, therefore, of courſe, will be but very ſhort; and yet ſome conſiderable advantages to both theſe Sciences will be derived from it.

Though *Philolaus* had, with ſome few *Pythagoreans*, taught, as we have ſeen, the *annual* motion of the Earth about the Sun, and *Hicetas* had aſſerted the *diurnal* motion of the Earth about its own axis, yet it appears that neither of theſe concluſions were univerſally embraced; for

PTOLEMY's SYSTEM,



as is well known, was nothing more than the vulgar one. Here the Earth is made the center of motion of all the Planets, the lowermoſt of which is the Moon, next her is *Mercury*, then *Venus*, then the Sun, then *Mars*, next him *Jupiter*, and laſtly, the outermoſt of all, *Saturn*.

His catalogue of the fixed Stars is the oldeſt now extant; and this, perhaps, is the catalogue begun, if not compleated, by *Hipparchus*. For

Hiſtory mentions no perſon that attempted any thing of this nature before him: and it doth not appear that any one between his time and *Ptolemy*'s made any addition to it.

In this catalogue the Longitudes and Latitudes of the fixed Stars are, for the firſt time, referred to the Ecliptic; for there is no inſtance of its being done ſo before. The *Jeſuits*, who are apt to magnify the *Chineſe* Aſtronomy, allow that their Aſtronomers did nothing of this kind till about the year after Chriſt 99 *; ſo that it was, probably, no invention of their own, but learned from the *Greeks*, who traded with them from *Egypt*. For that the *Greeks* ſailed very far to the eaſtward, appears, ſufficiently enough, from the *Minor Geographers*, as they are called, publiſhed by Dr. *Hudſon* at *Oxford*.

And that the *Egyptians* extended their commerce very far that way, appears from many inſtances. *Martini* ſays †, that the *ancient Chineſe* characters differ widely from the *modern*, and are not much unlike the *Egyptian* characters upon the obeliſks at *Rome*; there are, beſides, many traces of *Egyptian* cuſtoms ſtill extant in the Eaſt. In the kingdom of *Orixa*, the temple of *Jagarynat* is built in form of a large tun, or *Canary* pipe, as we learn from *Hamilton*'s Voyages ‡. About the middle of it is an *ox* cut out in one intire ſtone, bigger than the life. In the ſame kingdom, likewiſe, is another pagod where *fiſh* are worſhipped.

This is farther confirmed from the *Gentows* at *Goa*, and even from the converts made there by the *Portugueſe*, "who retain ſo much of the an-
"cient heatheniſh ſuperſtition (ſays Captain *Hamilton*, who was in the
"country) that they abſtain from eating cow's fleſh, becauſe of the
"veneration paid to that beaſt, above others, by the *Gentows*, whoſe off-
"ſpring they are §."

The ſame likewiſe is confirmed from the *Banyans* at *Gambroon*, "who
"give the ſhanaſheen, or governor, a yearly preſent of value, to pro-
"hibit cow-killing; for they worſhip that beaſt in as great a degree of
"veneration as a Papiſt doth the image of a ſaint.---Their books are as
"numerous, and their traditions and legends as full, in relating prophecies
"uttered by the cow, as well as miracles performed by her, as the others
"can boaſt of done by their images ||."

Add to this that general veneration ſtill paid all along that part of the Aſiatic coaſt to the cow, the great deity of the *Egyptians*. *R. Peritzol*, who is a leſs trifler than the authors of his nation generally are, ſpeaking of

* Obſervat. Mathemat. Aſtron. &c. vol. ii. p. 23. † Page 23. ‡ Vol. i. p. 386.
§ Hamilt. Voyag. vol. i. p. 251. || Hamilt. ut ſup. p. 97.

the

the islands about *Calecut*, says, ויש מקומות אשר יש משפט מות להורג פרה וגו *Suntque loca ubi judicium est mortis interficienti vaccam aut bovem* *. This author wrote A. D. 1525. *Calecut* lies in the empire of the Great Mogul, in Long. from *London* 74° 50′ East, and Latitude 11° North. And *Gordon*, speaking of the religion of the Mogul's subjects, says, "They have the greatest veneration for the cow, to whom they pay a "solemn address every morning †."

By comparing the place of the *Spica Virginis*, as observed by *Timocharis*, and afterwards by *Hipparchus*, and then by himself, *Ptolemy* stated what is now called the *Precession of the Equinox* to be at the rate of one degree in an hundred years.

It is now commonly supposed to be at the rate of one degree in seventy-two years only: and this is the same as it is made by Dr. *Halley* in his tables; or at the rate of 1° 23′ 20″ in 100 years.

Cassini makes it at the rate of 1° 25′ 43″ in 100 years.

But Mr. *De la Lande* ‡ makes it to be at the rate of 1° 23′ 53″ 6. in 100 years; which doth not differ much from Dr. *Halley*'s determination above.

Under this head of the *Precession of the Equinox*, it may not be improper to observe, that, if we suppose it to be, with *Hipparchus* and *Ptolemy*, at the rate of one degree in 100 years, it will be

1° : 100y :: 360° : 36,000y

This was called the Αποκαθάστασις, or *Restitution* of the fixed Stars by the ancients, after *Hipparchus*; because in that time all the fixed Stars return to their first position with respect to the Colures. But others, mistaking this *Restitution*, which is a thing purely astronomical, supposed there would be a *Restitution* of all human affairs and transactions, which would come about in the same order again. And it is to this opinion that *Virgil* alludes §.

Alter erit tum Tiphys, & altera quæ vehat Argo
Delectos heroas: erunt etiam altera bella,
Atque iterum ad Trojam magnus mittetur Achilles.

In what manner this *Precession of the Equinox* is to be accounted for, we shall see hereafter. In the mean time, it will be highly proper to observe what uses may be made of it, by attending to the following Propositions.

* Page 170. † Geog. Gram. p. 259. ‡ Connois. des Mouvem Celest. for 1762.
§ Eclogue iv.

But first of all it may be remarked, that this slow motion of the fixed Stars *forwards*, is really caused by a like slow motion of the equinoctial points *backwards*, and that this is owing to the revolution of the axis of the Equator about the axis of the Ecliptic; the Pole of the Equator describing in the Heavens a Circle about the Pole of the Ecliptic, as a center, as will be explained by the following contrivance on some of *Senex*'s Globes.

In a Globe of this sort, the Poles of the diurnal motion do not enter into the Globe, but are fixed at one end to two arms of brass, at the distance of 23 degrees and a half from the Poles of the Ecliptic. These arms, at the other end, are strongly fastened on to an iron axis, which passes through the Poles of the Ecliptic, and is made to move round, but with a very stiff motion, so that when it is adjusted to any part of the Ecliptic which you desire the Equator may intersect, the diurnal motion of the Globe on its axis will not be able to disturb it.

When it is to be adjusted for any time, past or to come, bring the northern arm under the Meridian, and fix it there by means of the brass nut, which is made like the nut of a Quadrant of Altitude, sliding it into the two notches of the brass arm, and screwing it fast; and when it is thus fixed, turn the Globe so about, that the point of the Ecliptic you would have the Equator intersect, may pass under the point of the brazen Meridian marked Æ. Then if you hold a pencil perpencicular to that point, and turn the Globe about, it will describe the Equator, as it was posited at that time; and if you transfer the pencil to 23 degrees and a half and 66 degrees and a half on the brazen Meridian, the Tropics and Polar Circles will be described for the same time.

We come now to the Propositions themselves.

PROPOSITION I.

The time being given, to find the *Precession of the Equinox*.

Let the time given be 1916 years. Then since the *Precession*, as was said, is at the rate of one degree in 72 years, say,

As 72 years : 1° : : 1916 years : 26° The equinoctial points, therefore, have gone *backwards* 26° in 1916 years; or the fixed Stars will appear to have gone *forwards* so many degrees in that time.

PROPOSITION

PROPOSITION II.

The Preceſſion of the Equinox being given, to find the time.

This Propoſition is only the *converſe* of the former. Let the Preceſſion given be 26°. Therefore ſay,

1° : 72 years : : 26° : 1916 years.

N. B. The numbers 72 and 1° the two firſt in the proportion, being conſtant numbers, the time will always be found by multiplying the given Preceſſion by 72.

Thus likewiſe 24, if multiplied by 72, gives 1728, and $24\frac{1}{2} \times 72 = 1764$ years. Therefore, *vice verſa*, the number of years (1764) divided by the conſtant number 72, will give the Preceſſion for the time, as under the laſt Problem.

PROPOSITION III.

The Preceſſion of the Equinox being given, to find the poſition of the vernal and autumnal interſections of the Ecliptic with the Equator.

Faſten the braſs arm under the Meridian, by means of the little braſs nut, and turn the Globe backward, if the time be paſt, or forward, if it be to come, till as many degrees paſs under the braſs Meridian as the Preceſſion conſiſts of; unſcrew the nut, and let the Globe turn upon the axis of the Equator. Mark that point of the Ecliptic which comes under the point on the braſs Meridian marked Æ; that point will be the vernal interſection of the Ecliptic with the Equator, and the point oppoſite to it, or 180 degrees diſtant from it, will be the autumnal interſection.

EXAMPLE.

Let the given Preceſſion be 26 degrees and a half. Faſten the braſs arm under the north part of the Meridian, and if the time be paſt, turn the Globe backward, till 26 degrees and a half come under the braſs Meridian; then unſcrewing the nut, let the Globe turn on the axis of the Equator, and you will find *Aries*, 26 degrees and a half, will come under the point on the brazen Meridian marked Æ, and conſequently will ſhew the vernal interſection for that time, as *Libra* 26 degrees and a half will ſhew the autumnal interſection.

PROPOSITION

PROPOSITION IV.

The Preceſſion of the Equinox being given, to find the Equinoctial, Tropical, and Polar Circles for that time.

Find the vernal interſection for the time by the laſt Propoſition; then holding a pencil perpendicular to the Globe at the point on the braſs Meridian marked Æ, and turning the Globe about on the axis of the Equator, the pencil will deſcribe the Equinoctial Circle for that time.

Then removing the pencil to 23 degrees and a half on the braſs Meridian, on each ſide of the point Æ, and holding it perpendicular, the pencil will ſhew the Tropical Circles for the ſame time.

And if the pencil be held perpendicular to the Globe at the diſtance of 23 degrees and a half from each Pole, then turning the Globe about on the axis of the Equator, it will deſcribe the Polar Circles for the ſame time.

COROL.

Hence it follows, that having the Equator and Tropical Circles for the time, there may be drawn a new Ecliptic; and from thence may be found all the Stars that then lay in the way of the Sun and Moon.

PROPOSITION V.

The Preceſſion of the Equinox being given, to find the poſition of the Colures at any time paſt, or to come.

Let the time given be paſt, and let the poſition of the ſolſtitial Colure be required.

Bring the braſs arm under the North part of the braſs Meridian, and with the braſs nut ſcrew it faſt; then turn the Globe about the axis of the Ecliptic from the right hand to the left, till as many degrees paſs under the braſs Meridian as the Preceſſion requires. The braſs Meridian will then paſs over all thoſe Stars through which the ſolſtitial Colure at that time paſſed.

If the time given be to come, the Globe muſt be turned from the left hand to the right, and the reſt of the operation will be the ſame.

EXAMPLE.

EXAMPLE.

Let the time given be 1916 years paſt. The Preceſſion for that time was found, by Prop. I. to be 26 degrees. Turn the Globe from right to left, till 26 degrees paſs under the braſs Meridian; that will ſhew the poſition of the ſolſtitial Colure 1916 years ago.

If the poſition of the equinoctial Colure be ſought for the ſame time, then unſcrewing the nut, let the Globe turn about the axis of the Equator, till 26 degrees of *Aries* or *Libra* come under the point on the braſs Meridian marked Æ; then holding the Globe in that poſition, the braſs Meridian will lie over all thoſe Stars through which the equinoctial Colure at time paſſed.

PROPOSITION VI.

The poſition of the Colure being given, to find the time.

Having ſcrewed faſt the braſs arm under the North part of the braſs Meridian, turn the Globe backward, if the time be paſt, or forward, if it be to come, till the given Stars lie under the braſs Meridian; if the given Colure be the ſolſtitial, mark the number of degrees in the Ecliptic in the mean while paſſing under the Meridian; multiply them by 72, and the product will give the time required.

EXAMPLE.

Hipparchus ſays, Ἐπὶ μὲν οὖν τῶ διὰ τῶν Τροπικῶν Σημείων καὶ διὰ τῶν Πόλων γραφομένῳ Κύκλῳ, κεῖται Ἀςὴρ ὁ ἐν ἄκρᾳ τῇ οὐρᾷ τῶ Κυν*. *i. e.* that in his time the ſolſtitial Colure paſſed through the Star in the tip of the *Dog's Tail.*

Turn the Globe till the braſs Meridian paſs over the Star in the tip of the tail of the great *Dog*. The number of degrees paſſing under the braſs Meridian in the mean while appear to be twenty-ſix and a half; theſe, multiplied by ſeventy-two, will give 1908 years for the time required.

If the poſition of the equinoctial Colure be given, bring the Star through which it paſſed up to the braſs Meridian, and mark what point in the Ecliptic comes up to it along with the Star. Count the number of degrees between that point and the beginning of *Aries*.

* Petav. Uranolog. p. 252.

Faſten

Faſten the baſs arm, as before directed, and turn the Globe about, till the number of degrees, juſt now found, paſs under the braſs Meridian; then unſcrewing the nut, let the Globe turn about the axis of the Equator, the point in the Ecliptic, before found, will come under the point on the braſs Meridian marked Æ, and the braſs Meridian itſelf will lie over the given Star, and conſequently will ſhew the poſition of the equinoctial colure for the given time.

The number of degrees on the Ecliptic, above found, multiplied by 72, will give the time required.

EXAMPLE.

Εν δὲ τῷ ἑτέρῳ Κολούρῳ φησὶ κεῖσθαι ὁ μὲν τὴν ἀριστερὰν χεῖρα τοῦ Ἀρκτοφύλακος, καὶ μέσα αὐτοῦ καλὰ Μῆκος. Εἶτα τὰ μέσα τῶν χηλῶν κατὰ πλάτος, καὶ τοῦ Κενταύρου τὴν δεξίαν χεῖρα, καὶ τὰ ἐμπρόσθια γόνατα. Μετὰ δὲ τὸν ἀφανῆ Πολον, καμπήν τε τοῦ Ποταμοῦ, καὶ Κήτους τὴν Κεφαλήν, καὶ τοῦ Κριοῦ τὰ νῶτα κατὰ πλάτος, καὶ τοῦ Περσέως τὴν Κεφαλὴν, καὶ τὴν δεξιὰν χεῖρα. "That is (ſays "*Hipparchus*) he (*Eudoxus*) informs us, that in the other Colure (*i. e.* "the equinoctial Colure) lies the left hand of *Arctophylax*, and the mid- "dle of him, reckoning lengthways; that it then proceeds through the "middle of *Chelæ*, the right hand and fore knees of the *Centaur*, the "*South Pole*, the flexure of the *River*, the head of the *Whale*, the "back of *Aries*, and the head and right hand of *Perſeus* *."

In the right hand of *Perſeus* is a ſmall Star, in *Bayer*'s catalogue marked h. Bring that to the braſs Meridian, and the point of the Ecliptic coming up along with it will be *Aries* thirty degrees. Faſten the braſs arm, as before, and paſs thirty degrees under the brazen Meridian; then unſcrewing the nut, turn the Globe about the axis of the Equator, and *Aries* thirty degrees on the Ecliptic will come under the point on the brazen Meridian marked Æ, and the brazen Meridian will paſs over the Star h in the right hand of *Perſeus*, and conſequently ſhews the poſition of the equinoctial Colure in the time of *Eudoxus*; then thirty multiplied by ſeventy-two, will give 2160 years for the time.

* See Petav. Uranolog. p. 208.

SCHOLIUM.

SCHOLIUM.

The equinoctial Colure here drawn paſſeth through a particular Star in the right hand of *Perſeus*, though no particular Star be mentioned by *Eudoxus*. It appears at the ſame time, likewiſe, that the Colure paſſing through this Star will not paſs over the back of *Aries*, nor through the flexure of *Eridanus*; therefore theſe obſervations of the ancients are not to be looked upon as very accurate.

In the flexure of *Eridanus* is a ſmall Star, by *Bayer* marked π. But in order to make the equinoctial Colure paſs through that Star, we muſt turn the Globe till 43° in the Ecliptic paſs under the braſs Meridian.

Then 43° multiplied by 72 will give for the time no leſs than - - - - - - - 3096 years.
From which ſubtracting 2016 above,
The difference will be 1080

So that the Colure paſſed through that Star in the flexure of *Eridanus* 1080 years before the time that it paſſed through the Star in the right hand of *Perſeus*.

Having ſeen in what manner, the poſition of the Colure being given, we may find the time when it had that poſition, we may proceed to take notice what uſe may be made of this Problem in a very remarkable point of hiſtory, the

ARGONAUTIC EXPEDITION.

It is well known that the hiſtory of the *Greeks* goes no higher than the time of the Argonautic Expedition, and that this, whatever was the true occaſion of it, was the earlieſt enterprize undertaken by that people in a body. But how early this was, is a point much controverted by chronologers. *Petavius* * places it in the year before Chriſt 1226.

Sir *Iſaac Newton*, in his Chronology †, places it about forty-three years after the death of *Solomon*; and in his ſhort Chronicle ‡, in the year before Chriſt 937. Not to enter here into the reſt of his reaſoning, which would be foreign to our purpoſe, there is one argument by which he endeavours to ſupport his hypotheſis, and which is commonly known by the name of his *aſtronomical Argument*.

* Rat. Temp. p. 36. † Page 94. ‡ Page 26.

It is taken from the *position of the Colures* at the time of the Argonautic Expedition, and therefore may properly enough be introduced here, as an illustration of the subject before us. But in order to understand the force of his argument, it must be observed, that,

I. He supposes that *Chiron* was a practical Astronomer;---that he formed the first Sphere, or was the first person among the *Greeks*, at least, that formed the Stars into Assemblages, or Constellations;---and that he did this for the use of the Argonauts, who were to sail by night. This he supposes, on the authority of the author of the *Gigantomachia*, cited by *Clemens Alexandrinus* *.

II. He supposes that *Chiron* placed his Colures so as to pass through the middle of his equinoctial and solstitial Signs; that is, he made his equinoctial Colure pass over the back of *Aries*, and through the middle of *Chelæ*; and his solstitial Colure to pass through the middle of *Cancer*, and the middle of *Capricorn*.

III. That the Precession of the Equinox was unknown in the time of *Eudoxus*; and therefore that when he makes the Colures to pass through the middle of the Signs, as *Hipparchus*, in the passage quoted above, says he did, it was doing nothing more than supposing that they continued in the same place where they had been fixed by the person who first delineated them, *i. e.* as was seen above, by *Chiron*.

IV. That when the Colures are made to pass through the middle of the Signs, that term is not precise enough to determine their true position; therefore, with regard to the equinoctial Colure, Sir *Isaac Newton* observes †, "that at the end of the year of our Lord 1689, the Star "called *Prima Arietis* was in *Aries* 28° 51′ 00″ with North Latitude "7° 8′ 58″ and the Star called *Ultima Caudæ Arietis* was in *Taurus* "19° 3′ 42″ with North Latitude 2° 34′ 5″ and the *Colurus equi-*"*noctiorum*, passing through the point in the middle between these Stars, "did then cut the Ecliptic in *Taurus* 6° 44′; and by this reckoning, the "Equinox, in the end of the year 1689, was gone back 36° 44′ since "the Argonautic Expedition, supposing that the said Colure passed "through the middle of the Constellation *Aries*, according to the de-"lineation of the ancients. The Equinox (continues he) goes back "fifty seconds in one year, and one degree in seventy and two years, "and by consequence 36° 44′ in 2645 years, which, counted back from "the end of the year of our Lord 1689, or, beginning of the year 1690, "will place the Argonautic Expedition about 25 years after the death "of *Solomon*."

* Strom. i. p. 306—352. See his Chron. p. 83. † Page 86.

PROPO-

PROPOSITION VII.

The Latitude of the place, and the Preceſſion of the Equinox being given, to find the Arctic Circle, according to the manner of the ancients.

The Arctic Circle, found by the laſt Propoſition, is that drawn after the manner of the moderns, which is always at the diſtance of 23 degrees and a half from the Pole. But this poſition of the Arctic Circle, as before obſerved, is no older than the time of *Johannes à Sacro Boſco*.

Among the ancients, the diſtance of the Arctic Circle was variable, and always equal to the Latitude of the place; therefore having rectified the Globe for the Preceſſion of the Equinox by Prop. I. elevate the Pole till it becomes equal to the Latitude of the place; then holding a pencil at that point, turn the Globe about the axis of the Equator, and the pencil will deſcribe the Arctic Circle for that time and place.

EXAMPLE.

Hipparchus tells us, that ὁ Εὔδοξος καὶ τὰς ἐπὶ τῆ Αρκτικῆ Κύκλῳ κειμένας Ἀστέρας διασαφεῖ, καὶ φησιν ἐπ' αὐτῆ κεῖσθαι τόν τε ἀριστερὸν ὦμον τῆ Αρκτοφύλακος, καὶ τὰ ἄνωθεν τῆ στεφάνῃ, καὶ τὴν Κεφαλὴν τῆ διὰ τῶν Αρκτων Οφεως· τῆς δὲ Λύρας, καὶ τῆς δεξιᾶς Πτέρυγας τῆ Ορνιθος τὰ ἄνωθεν· τῆ δὲ Κηφέως τὸ Στῆθος· τῆς δὲ Κασσιεπείας τὰ ἄνωθεν. Εἶτα ὑπὸ τὰς ἐμπροσθίους Πόδας τῆς Μεγάλης Αρκτου, καὶ τῆ Λέοντος ἄχρι πρὸς τὸν ὦμον τῆ Αρκτοφύλακος. "*Eudoxus* de-"ſcribes the Stars lying in the Arctic Circle, and ſays that in it lie the left "ſhoulder of *Arctophylax*, and the ſpace over the *Crown*, and the head "of the *Dragon*, that lies between the two *Bears*, the ſpace above the "*Harp*, and the right wing of the *Swan*, that it goeth through the breaſt "of *Cepheus*, and the ſpace above *Caſſiopeia*; and that then it paſſeth under "the fore legs of the *Great Bear*, and ſo returns to the ſhoulder of "*Arctophylax* again *."

Eudoxus flouriſhed about 2120 years ago, the Preceſſion for which time is about 29 degrees and a half. He obſerved in the city of *Cnidus*, according to *Strabo* †, *i. e.* in about 36° North Latitude; therefore rectifying the Globe for the time by Prop. I. and for the Latitude, and holding a pencil at 36° upon turning the Globe about the axis of the Equator, we ſhall find it deſcribe a Circle, which will paſs through the right elbow of *Arc-*

* Petav. Uranolog. p. 206. † Page 180. Edit. Amſt.

tophylax, the head of *Draco*, the ſhoulder of *Cepheus*, *Caſſiopeia*'s chair, and the legs of the *Great Bear*.

PROPOSITION VIII.

The time being given, to find the Longitude of any known Star.

Find the place of the vernal interſection for the given time by Prop. III. and through the Pole of the Ecliptic and the known Star lay the Quadrant of Altitude, and obſerve the place in the Ecliptic where the point in the fiducial edge marked O falls. The diſtance between the vernal interſection and that point will give the Longitude of that Star.

EXAMPLE.

Let the time given be the ſame as in the laſt Example, and let the known Star be the *Capella*. Laying the Quadrant of Altitude through the Pole of the Ecliptic and the *Capella*, the point marked O will cut the Ecliptic in *Gemini* 19° *i. e.* 2 Signs 19° But the Preceſſion for the time in the laſt Example was 29 degrees and a half; therefore the vernal interſection was then in *Aries* 29° 30′.

	Therefore from	2ſ 19° 00′
	Subtracting	29° 30′
There remains the Longitude of the *Capella* =		1ſ 19° 30′

PROPOSITION IX.

The time being given, to find the right aſcenſion of any known Star.

Rectify the Globe for the given time, as before, and find the place of the vernal interſection; then through the Pole of the Equator and the known Star lay the Quadrant of Altitude, and mark the place where the point on the fiducial edge marked O falls. The diſtance between that place and the place of the vernal interſection will be the right aſcenſion of the known Star.

Otherwiſe, having rectified the Globe for the given time, deſcribe the equinoctial Circle for the ſame time by Prop. IV. then bring the Star up to the braſs Meridian, and mark that point of the *new Equinoctial* that comes under the point marked Æ. The diſtance between that point and the place of the vernal interſection, meaſured by the Quadrant of Altitude, will be the right aſcenſion of the known Star.

EXAMPLE.

EXAMPLE.

Let the given time and Star be the ſame as before. The place of the vernal interſection was found *Aries* 29° 30′. Deſcribe the Equinoctial through that point by Prop. IV. Bring the *Capella* up to the braſs Meridian, and mark the point of the new Equinoctial that comes up along with it under the point in the braſs Meridian marked Æ. The diſtance between that point and the place of the vernal interſection, meaſured by the Quadrant of Altitude, gives the right aſcenſion of the *Capella*, equal to 37 degrees and a half.

From this apparent ſlow motion of the fixed Stars forwards, it follows, that their right aſcenſions increaſe. At the beginning of the year 1760, the right aſcenſion of the *Capella* * was 74° 44′ 53″. Suppoſing it to have been 37° 30′ as found above, it will have increaſed 37° 14′ 53″.

This variation in right aſcenſion is not the ſame for all Stars. The mean annual variation of the *Capella* is 66″; but the mean annual variation of the Pole Star is 151″ or 2′ 31″. And in other Stars it will be different from theſe.

PROPOSITION X.

The time being given, to find the declination of a known Star.

Rectify the Globe for the time, and bring the Star up to the braſs Meridian. Mark the point in the Meridian directly over the Star; the arch of the Meridian intercepted between that point and the point on it marked Æ, will be the declination of the Star.

EXAMPLE.

Let the time and Star be the ſame as before; then bringing up the Star to the braſs Meridian, the point over it will be found 39° conſequently the declination of the *Capella* then was 39 deg.

COROLLARY I.

Hence the *polar diſtance* of any known Star, at any given time, will eaſily be had; for it is only the complement of the declination to 90 de-

* Connoiſ. des Temps pour l'Ann. 1764.

and

grees. Thus the declination of the *Capella* was found to be 39 degrees; and the complement of that to 90 degrees, or the *polar diſtance* of it, will be 51 degrees.

COROLLARY II.

The Latitudes of the fixed Stars are meaſured from the Ecliptic, and, till lately, were thought to continue, in all ages, the ſame; but their *declinations*, meaſured from the Equator, being different in different ages, and conſequently their *polar diſtances*, there will ariſe a *variation* in the *polar diſtance*, which will be eaſily obtained from this Propoſition; for it will be the *difference* between the *polar diſtances* of the ſame Star, taken at any two, or more, diſtinct times. Thus, *e. g.* the diſtance of the *Capilla* from the Pole, at the beginning of the year 1760, was 44° 16′; but by the Globe it was found 51°. The variation, therefore, in that time, will be 6° 44′.

And here it will not be improper to obſerve, that the variation in declination of different Stars is different. The mean annual variation of the *Capella* is 5″, but the mean annual variation of the Pole Star is 18″ *. And the variation of other Stars will be different from theſe.

PROPOSITION XI.

The Latitude of the place and the time being given, to find the oblique aſcenſion or deſcenſion of any known Star, together with the aſcenſional difference.

Rectify the Globe for the Latitude of the place, and for the time, and find the right aſcenſion of the Star by Prop. IX. Bring the Star to the edge of the eaſtern Horizon, and mark what degree of the Equator is then upon the Horizon along with it; that will be the oblique aſcenſion of the Star for that time and Latitude.

If the Star is brought to the edge of the weſtern Horizon, the point of the Equator then upon the Horizon will be the oblique deſcenſion of the Star for that time and Latitude; and the difference between the right aſcenſion and the oblique aſcenſion will be the aſcenſional difference.

* Connoiſ. des Tems pour l'Ann. 1764.

EXAMPLE.

EXAMPLE.

Let the Latitude of the place be 36° North, the given time as before, and the known Star the *Capella*.

Then by Prop. IX. the right aſcenſion of the *Capella* was found	37° 30′
And now the oblique aſcenſion of the *Capella* will be found	1° 30′
Therefore the aſcenſional difference for that time and Latitude will be - - - - -	36° 00′
Bring down the *Capella* to the weſtern ſide of the Horizon, and its oblique deſcenſion will be found - - - -	85° 00′
Its right aſcenſion, as before, was - - - -	37° 30′
Its oblique deſcenſion will be - - - - -	47° 30′

PROPOSITION XII.

The Latitude of the place and the time being given, to find the point of the Ecliptic riſing or ſetting with any known Star.

Rectify the Globe for the time and place, and bring the known Star to the edge of the eaſtern Horizon; that will ſhew the point of the Ecliptic riſing at the ſame time, as bringing the Star to the edge of the weſtern Horizon will ſhew the point of the Ecliptic ſetting along with it.

EXAMPLE.

Let the time given be 2658 years ago; the Preceſſion for this time by Prop. I. will be nearly 37 degrees. Let the Latitude of the place be 38 degrees North, and the known Star be *Arcturus*. Then bringing *Arcturus* down to the edge of the eaſtern Horizon, the point of the Ecliptic riſing along with it will be found to be *Libra* 10 degree 30 minutes.

And bringing it down to the edge of the weſtern Horizon, the point of the Ecliptic ſetting along with it will be found to be *Sagittarius* 27 degrees.

Arcturus is the Star here pitched upon, the rather, for the ſake of the following Propoſition. For from the achronycal riſing of *Arcturus*, mentioned by *Heſiod*, both *Scaliger* * and *Voſſius* † were of opinion that his age might be determined within ſeventy years.

* Animadverſ. ad Euſeb. Chron. No. 1255. † De Poet. Græc.

How

How far that is true, would be too long an enquiry for the preſent purpoſe.

PROPOSITION XIII.

The Latitude of the place and the time being given, to find the time of the year when a known Star roſe achronically.

Rectify the Globe for the Latitude of the place and the time, and bring the known Star to the edge of the eaſtern Horizon, and mark the point of the Ecliptic then ſetting in the Weſt. Find the diſtance of that point from the next equinoctial or ſolſtitial point behind it; and, ſuppoſing the Sun to deſcribe one degree in each day, the diſtance between theſe two points, converted into time, will give the day when the known Star roſe achronically. This will be beſt explained by the

EXAMPLE.

Heſiod ſays, that ſixty days after the Winter Solſtice *Arcturus* roſe achronically *.

Ευτ' ἂν δ' ἑξήκοντα μετὰ Τροπὰς Ηελίοιο
Χειμέρι' ἐκτελέσῃ Ζεὺς Ηματα, δὴ ῥα τοῖ Αςὴρ
Αρκτῦρος, προλιπὼν ἱερὸν ῥόον Ωκεανοῖο,
Πρῶτον παμφαίνων ἐπιτέλλεται Ακρονύχιος.

When from the Solſtice ſixty wintry days
Their turns have finiſh'd, mark, with glittering rays,
From Ocean's ſacred flood *Arcturus* riſe,
Then firſt to gild the duſky evening ſkies.

The time when *Heſiod* lived is much controverted. It ſhall here be taken for granted that it was about 900 years before Chriſt; the Preceſſion for which time is nearly 37 degrees.

He ſays himſelf that he lived at *Aſcra*, at the foot of *Mount Helicon*, whoſe Latitude, according to *Ptolemy*, is 37° 45′ North. We may take 38 degrees, which is nearly the Latitude of *Athens*, according to the beſt modern obſervations.

Rectify the Globe for this time and Latitude, and bring *Arcturus* to the edge of the eaſtern Horizon; the point of the Ecliptic ſetting in the Weſt will be found *Aries* 9° 30′.

* Lib. ii. ver. 185.

But

But the Preceſſion being 37° the ſolſtitial point in Summer was *Leo* 7° the point oppoſite to which, or the Winter Solſtice, was *Aquarius* 7° or 10ſ 7°

But *Aries* 9° 30′ is ♈	-	-	-	-	12ſ 9° 30′
From which if we ſubtract	-	-	-	-	10ſ 7° 00′
There will remain	-	-	-	-	2ſ 2° 30′

or 62° 30′, which in time will be 62 days and a half, and is as near to *Heſiod*'s determination as can be expected. For it is not certain that he made the obſervation himſelf, or any one in his time; or that it was made in, or near, the Latitude of *Athens*, it being no unuſual thing with the ancients to ſet down obſervations, as agreeing to one age and country, that were made at *different times*, and in *different places*; to which muſt likewiſe be added the difficulty of finding the day of the Solſtice in times much later than *Heſiod*'s. For *Hipparchus*, in *Ptolemy* *, acknowledges that he would not ſay, " that *Archimedes*, or himſelf, could not " miſtake *a quarter of a day*, either in the *obſervation* or *calculation* of " the Solſtice."

Neither is any notice here taken of *refractions* near the Horizon, by which Stars are elevated above their true place, and appear ſooner than they would otherwiſe do; that being a thing with which *Heſiod* was wholly unacquainted.

PROPOSITION XIV.

The Latitude of the place and the time being given, to find the point of the Ecliptic riſing when a known Star ſets.

Rectify the Globe for the Latitude of the place, and for the time, and bring the known Star to the edge of the weſtern Horizon, and mark the point of the Ecliptic then riſing in the Eaſt; that will be the point required.

EXAMPLE.

Let the given time be 2358 years ago; the Preceſſion for which time by Prop. I. will be 32 degrees 45 minutes. Let the Latitude of the place be 37 degrees North, and the known Star be the *Lucida Pleiadum*. Rectify the Globe for this time and Latitude, and bringing the *Lucida Pleiadum* to the edge of the weſtern Horizon, the point of the Ecliptic then riſing in the Eaſt will be found to be *Scorpio* 27 degrees.

* Syntax. l. iii. c. 2.

PROPOSITION XV.

The Latitude of the place and the time being given, to find the time of the year when a known Star ſet *comically*.

Rectify the Globe for the Latitude of the place, and for the time; then bring the known Star to the edge of the weſtern Horizon, and at the ſame time mark the point of the Ecliptic riſing in the Eaſt; that point will be the Sun's place. Count the number of degrees between that point and the laſt equinoctial or ſolſtitial point behind it. Then ſuppoſing the Sun to deſcribe one degree in each day, the diſtance between the points juſt found, in time, will give the day when the known Star ſet *coſmically*.

EXAMPLE.

Pliny ſays *, that *Thales* determined the *coſmical* ſetting of the *Pleiades* to be 25 days after the *autumnal Equinox*. Where this obſervation was made, is not ſaid: let us ſuppoſe it was at *Miletus*, whoſe Latitude, according to *Ptolemy*, is 37 degrees North. *Thales* lived about the year before Chriſt 600, *i. e.* 2358 years ago; the Preceſſion for which time is 32 degrees 45 minutes.

Rectify the Globe for this time and Latitude, and bring the *Lucida Pleiadum* to the edge of the weſtern Horizon; the point of the Ecliptic then riſing will be found, as by the laſt Propoſition, *Scorpio* 27 degrees. But the place of the autumnal interſection was, at that time, *Scorpio* 2 degrees 45 minutes; but the diſtance between that point and *Scorpio* 27 degrees is 24 degrees 15 minutes, which, allowing one degree to a day, the Sun will deſcribe in a little more than 24 days.

This is as near the determination of *Thales* as can be expected, conſidering that it is uncertain how far the true time of the Equinoxes were known in his days. The obſervation itſelf might have been made before his time, as the Preceſſion of the Equinox was not then ſo much as ſuſpected, nor, as obſerved before, were the ancients careful to mark the places where the obſervation was made, that ſo the Latitude may be known; which hath been the occaſion of great confuſion in their accounts.

* Nat. Hiſt. lib. xviii. cap. 25.

PROPOSITION.

PROPOSITION XVI.

The Latitude of the place and the time being given, to find the Sun's place, when he comes ſo near to a given Star, that it appears, for the laſt time, in the evening before it is intirely hid by the Sun-beams, or, which is the ſame thing, the Latitude of the place and the time being given, to find the *heliacal* ſetting of a known Star.

In order to determine this Problem, it will be neceſſary to obſerve, that Stars riſe and ſet heliacally, when the Sun is depreſſed, perpendicularly, a certain number of degrees below the Horizon. According to *Ptolemy*, Stars of the firſt magnitude require the Sun to be depreſſed 12 degrees, Stars of the ſecond magnitude require the Sun's depreſſion to be 13 degrees, Stars of the third magnitude 14 degrees, and ſo on.

This being premiſed, rectify the Globe for the Latitude of the place and the time, and bring the known Star to the edge of the weſtern Horizon. Fix the Quadrant of Altitude in the Zenith of the place, and turn it about, till the fiducial edge cuts the Ecliptic on the eaſtern ſide of the Meridian in 12 degrees of altitude, if the Star be of the firſt magnitude; in 13 degrees, if of the ſecond, and ſo on; the point of the Ecliptic oppoſite to this will be the ſame number of degrees below the Horizon as this is elevated above, and conſequently will be the Sun's place when the known Star ſet *heliacally*.

EXAMPLE.

Let the time given be 1760 years ago. The Preceſſion for this time will be by Prop. I. about 24 degrees 30 minutes. Let the Latitude of the place be 42 degrees, which is nearly the Latitude of *Rome*, and let the known Star be the bright Star of the ſecond magnitude, as *Ptolemy* makes it, in the extremity of the *Bull*'s horn. It is the ſame, likewiſe, that is in the right foot of *Auriga*.

Rectify the Globe for the time and Latitude, and bring the Star to the edge of the weſtern Horizon. Screw on the Quadrant of Altitude at 42 degrees, the Zenith of *Rome* nearly, and turning it about on the eaſtern ſide of the Meridian, till 13 degrees of altitude cut the Ecliptic, that point will be found *Sagittarius* ſeven degrees; the point oppoſite to which is *Gemini* ſeven degrees. The bright Star, therefore, in the extremity of the *Bull*'s horn, at that time, and in that Latitude, ſet *heliacally* when the Sun was in ſeven degrees of *Gemini*.

PROPOSITION XVII.

The Latitude of the place and the time being given, to find the time of the year when a known Star ſet heliacally.

Rectify the Globe for the Latitude and the time, and find the Sun's place, by the laſt Propoſition, when the known Star ſet heliacally; the diſtance between that place and the next equinoctial or ſolſtitial points for the time laſt paſt, ſuppoſing the Sun's motion to be one degree each day, as before, will give the time of the year required.

EXAMPLE.

Let the Latitude of the place, the time, and Star, be the ſame as in the laſt Propoſition; the place of the Sun, when that Star ſet heliacally, at that time, and in that Latitude, was, by the laſt Propoſition, found to be *Gemini* ſeven degrees. But the place of the vernal interſection then was, by the laſt Propoſition, *Aries* 24 degrees.

If then from	-	-	-	-	$2^{s}\ 07^{\circ}$
We ſubtract	-	-	-	-	$0^{s}\ 24^{\circ}$
There will remain	-	-	-	-	$1^{s}\ 13^{\circ} = 43^{\circ}$

This, turned into time, will give 43 days; ſo that this Star ſet heliacally 43 days after the vernal Equinox, at that time, and in that Latitude. It might be of this ſetting of this Star that *Virgil* ſpeaks, when he ſays *,

--------- Milio venit annua cura
Candidus auratis aperit cum cornibus annum
Taurus, & adverſo cedens Canis occidit Aſtro.

And Millet ſtill ſucceds an annual care,
When with his horns the *Bull* unbars the year,
And frighten'd flies the *Dog*, and ſhuns the adverſe Star.

But as no particular Star is mentioned by the Poet, he may mean nothing more than, in general, that Millet was to be ſowed when the Sun entered *Taurus*, which, according to *Columella*, was the 17th of *April*.

* Georg. i. ver. 217.

PROPOSITION.

PROPOSITION XVIII.

The Latitude of the place and the time being given, to find the place of the Sun, when he is got ſo far beyond a given Star that it appears, for the firſt time, in the morning before Sun-riſe, *i. e.* The Latitude of the place and the time being given, to find the *heliacal* riſing of any known Star.

Rectify the Globe for the Latitude of the place and the time, and bring the known Star to the edge of the eaſtern Horizon. Fix the Quadrant of Altitude in the Zenith of the place, and if the Star be of the firſt magnitude, turn it about, till the fiducial edge cuts the Ecliptic on the weſtern ſide of the Meridian in 12 degrees of altitude; if the Star be of the ſecond magnitude, in 13 degrees of altitude, *&c.* the point of the Ecliptic oppoſite to that will be the place of the Sun required.

EXAMPLE.

Let the Latitude of the place and the time be the ſame as in the laſt Propoſition, and let the known Star be *the bright Star in the Crown.* This, according to *Ptolemy*, is a Star of the ſecond magnitude. Bring this Star to the edge of the eaſtern Horizon, and fixing the Quadrant of altitude at 42 degrees on the braſs Meridian, and turning it about on the weſtern ſide of the Meridian, it will cut the Ecliptic at 13 degrees of altitude in *Taurus* four degrees, the point oppoſite to which is *Scorpio* four degrees, the place of the Sun required.

PROPOSITION XIX.

The Latitude of the place and the time being given, to find the time of the year when a known Star roſe *heliacally*.

Rectify the Globe for the Latitude of the place, and for the time, and find, by the laſt Propoſition, the Sun's place, when the known Star roſe heliacally. Count the number of degrees intercepted between the Sun's place, juſt found, and the equinoctial or ſolſtitial point laſt paſt; thoſe degrees turned into time, as before, will give the time of the year when the known Star roſe *heliacally*.

EXAMPLE

EXAMPLE.

Let the Latitude of the place, the time, and the Star, be the same as in the last Propoſition. The place of the Sun at that time, and in that Latitude, when *the bright Star in the Crown* roſe heliacally, was found, by the laſt Propoſition, to have been *Scorpio* four degrees. But the place of the autumnal interſection, at that time, was found, by Prop. XVI. to have been *Libra* 24 degrees.

If, therefore, from	- - -	$7^s\ 04^\circ$
We ſubtract	- - - -	$6^s\ 24^\circ$
There remains	- - - -	$0^s\ 10^\circ$

This, ſuppoſing, as before, the Sun to deſcribe one degree each day, will give ten days. So that the bright Star in the *Crown* roſe heliacally then, in the Latitude of *Rome*, ten days after the *autumnal Equinox*.

SCHOLIUM.

It is of this riſing of *Ariadne's Crown* that *Virgil* is ſuppoſed to ſpeak *, when he adviſeth, in plowing for wheat,

Ante tibi eoæ atlantides abſcondantur,
Gnoſiaque ardentis decedat Stella Coronæ.

First let the Siſters in the morn go down,
And from the Sun retire the Gnoſſian Crown.

Before we diſmiſs this article of Aſtronomy under *Ptolemy*, it will not be quite foreign to the purpoſe to add ſomething with relation to that diviſion of time now ſo well known, and called

A WEEK.

This is a ſyſtem of ſeven days, regularly ſucceeding each other throughout the year.

The firſt mention that we find of this diviſion of time into weeks, or rather of the term week, is *Gen.* xxix. 27. where *Laban* propoſes to *Jacob* to fulfil *Leah's week*. This ſome underſtand of the ſeven days that the nuptial feaſt was kept; but others of a *ſeptenary* of years that

* Georg. lib. i. ver. 222.

Jacob

Jacob was to ſerve for *Rachel*. But the former ſeems the more reaſonable interpretation *.

Whether any people divided their time by *ſeptenaries* of days, or weeks, properly ſo called, beſides the *Jews*, may be doubted. *Joſephus* ſays †, Οὐδ' ἔστιν ἡ πόλις Ελλήνων ἠδετισῶν, οὐδὲ Βάρβαρος, οὐδὲ ἔν ἔθνος, ἔνθα μὴ τὸ τῆς Εβδομάδος, ἣν ἀργοῦμεν ἡμεῖς, τὸ ἔθος ἡ διαπεφοίτηκε. *There is no city of the* Greeks, *or* Barbarians, *nor* any one nation, *whither the cuſtom of obſerving the ſeventh day, which we keep holiday, hath not travelled.* And *Ariſtobulus*, a *Jew*, and peripatetic Philoſopher, in *Euſebius* ‡, ſpeaking of the creation, and the *ſabbath* of his countrymen, adds, Διασαφεῖ Ομηρος καὶ Ησίοδος, μεμελετηφότες ἐκ τῶν ἡμετέρων βιβλίων, ἱερὰν εἶναι. *Both* Homer *and* Heſiod *call it* holy, *plainly borrowing that appellation from our books.* And then he cites this line from *Heſiod* §.

Πρῶτον εἶνη, τετράς τε, καὶ ἑβδόμη, ἱερὸν ἦμαρ.

Primum prima, deinde quarta, & ſeptima, dies ſacra.

And likewiſe this line from *Homer*.

Ἑβδόματη δ' ἔπειτα καλήλυθεν, ἱερὸν ἦμαρ.

Septima *dein illuxit*, ſacra dies.

Clemens Alexandrinus ‖ ſays, ἀλλὰ καὶ τὴν ἑβδόμην ἱερὰν, ἣ μόνον οἱ Εβραῖοι, ἀλλὰ καὶ οἱ Ελληνες ἴσασι; *that the ſeventh day is* holy, *not only the* Hebrews, *but the* Greeks *likewiſe, know.*

But in the paſſages cited above by *Ariſtobulus*, from *Homer* and *Heſiod*, he either ignorantly, or wilfully, miſtook their meaning: for that *Heſiod* did not underſtand *every* ſeventh day in each month, *returning* in a *Cycle*, but *ſimply* the ſeventh day of the month, appears from the reaſon aſſigned by him in the line immediately following.

Τῇ γὰρ Απόλλωνα χρυσάορα γείνατο Λητώ.

For on that day (*i. e.* on the 7th day of ſome month, or the month *Thargelion*, as the people of *Delos* ſaid) Latona *brought forth* Apollo; and therefore the *ſeventh* day of each month is to be looked upon as *ſacred*, or particularly *lucky*. And ſo *Heſiod* uſes the words ἱερὸν ἦμαρ again ¶.

The line here cited from *Homer* is not to be met with in any of the preſent editions. But the word ἑβδομάτη (*i. e.* ἡμέρα) occurs in ſeveral

* See Ainſworth, and the Jeruſalem Targum there, with other Commentators.
† Cont. Apion. lib. ii. cap. 39. ‡ De Præparat. Evang. lib. xiii. cap. 12. § Hemer. ver. 6.
‖ Stromat v. ¶ Ver. 55.

places

places of that poet, as *Odyſſ.* K. ver. 81. and Ξ. ver. 252. and yet in none of them can poſſibly be underſtood of a *Cycle* of *ſeven* days.

The epithet of ἱερὸν, or *ſacred*, is applied to the day *indefinitely* by *Homer*; and therefore is not to be underſtood in a *religious* ſenſe. Thus *Illiad* Θ. ver. 66.

Ὄφρα μὲν Ἠὼς ἦν, καὶ ἀέξετο ἱερὸν ἦμαρ.

While it was morning, and the ſacred *day increaſed.*

The very ſame expreſſion occurs again, *Illiad* Λ. ver. 84. and *Odyſſ.* I. ver. 56. and in the ſame ſenſe.

As to the paſſage cited above from *Clemens Alexandrinus*, the meaning is, according to Mr. *Selden* *, not that the *Greeks*, as well as the *Hebrews*, looked upon the *ſeventh* day of the week, or every *ſeventh* recurring day, to be holy; but that the *Greeks*, as well as the *Hebrews*, held the number *ſeven* in eſteem, and therefore, in a manner, *ſacred*: and that they did ſo, he proves from the authority of ſeveral authors, there quoted by him. But this interpretation of his ſeems forced. *Clemens* was a Sophiſt; and it is well known that it was a cuſtom with them to prove their point by any arguments they could think of, whether true or falſe. No wonder, therefore, they ſhould ſometimes catch at ſounds, as ſeems to have been the caſe with *Clemens* in this place. That the number ſeven was held in great eſteem among other nations, beſides the *Jews*, and very early too, appears, I think, from *Numb.* xxiii. 1. where *Balaam* propoſes to *Balak*, in order to procure the divine favour, to build him *ſeven* altars; "and prepare me here (ſays he) *ſeven* oxen, and *ſeven* "rams." And the marriage-feaſt was kept *ſeven* days, we ſee, as early as the time of *Jacob* and *Laban*, which, probably, was done on account of ſome luckineſs ſuppoſed to be in the number *ſeven*, from whenceſoever that luckineſs might be derived.

But this is nothing to the diſtribution of time into weeks, or a ſyſtem of *ſeven* days, recurring, or regularly ſucceeding each other, throughout the year, and as obſerved by any people beſides the *Jews*, and from them afterwards by the Chriſtians.

But whether the diſtribution of time by weeks, in which every ſeventh recurring day was holy, was in uſe among the *Jews* themſelves before the giving of the Law at *Mount Sinai*, hath been made a doubt of. The fourth Commandment, indeed, begins with the word REMEMBER, which ſeems to imply, that the inſtitution of keeping holy the *ſeventh*

* De Jur. Nat. & Gent. lib. iii. cap. 17.

day

day was older than the time of giving the reſt of the Law; but when it commenced, the *Jews* themſelves are at a loſs to determine. Nor is that any wonder; for they know nothing of their ancient hiſtory, any farther than what they meet with in their books of the Old Teſtament, and with which we are acquainted as well, if not better, than they are. From the precept relating to the gathering of manna, *Exod.* xvi. it is plain the Sabbath was obſerved before the Law was given at *Sinai*; but whether it was firſt inſtituted upon that occaſion, is not equally clear.

R. Jehuda Hallevi, who wrote in *Spain*, about A. D. 1140, a cabaliſtical book, called *Sepher Cozri*, ſays, that this diſtribution of time is as old as *Adam*, and that from him it was propagated amongſt his poſterity. But this author is too late, and of too little authority, to be relied on in a caſe of this nature.

Michael Glycas quotes *Syncellus* as affirming that *Seth* invented the *Hebrew letters*, the *Conſtellations*, and the *diviſion of time* into *years*, *months*, and *weeks*. But *Syncellus*, who lived about A. D. 800, comes too late alſo to be of any authority in an affair of this nature. *Seth*'s pillars, mentioned by *Joſephus*, have been taken notice of before, and rejected as fabulous; and yet, perhaps, *Syncellus* had no better authority for his aſſertion than theſe ſuppoſed pillars of *Seth*. There is no mention of writing in any author before the giving of the Law at *Mount Sinai*; and the *Conſtellations* were, probably, the invention of much later times than even the flood itſelf. The reſt, therefore, that is here attributed to to *Seth*, depends upon as ſlender authority.

Johannes Philoponus, who flouriſhed about A. D. 600, ſays, Ἐκεῖνό γε μὲν συμπεφώνηται πᾶσιν ἀνθρώποις ἑπτὰ μόνας εἶναι ἡμέρας, αἵτινες εἰς ἑαυτὰς ἀνακυκλούμεναι τὸν ὅλον ποιοῦσι χρόνον. *There are, by the conſent of all mankind, but* ſeven *days, which, by their revolution, make up the whole of time.* But as this author ſpeaks at large, ſo may he be underſtood only with regard to the practice of his own time, long enough after the eſtabliſhment of Chriſtianity.

As to the paſſage cited from *Joſephus* above, Mr. *Selden* obſerves *, that the word ἑβδομάδος may be taken in a threefold acceptation; either,

I. Of the ſeventh day, as the ſeventh; that is, as a Feaſt, or Sabbath, obſerved upon a religious account, and by public inſtitution. But in this ſenſe, he ſays, the *ſeventh day* was not obſerved, at the time of *Joſephus*, by any but the *Jews*, and the Chriſtian Church, which was then in its infancy.

* De Jure Nat. & Gent. lib. iii. cap. 19.

II. It may be underſtood, as it was admitted into Calendars, Faſti, and public accounts of time, but without regard to any religious ceremonies.

In this ſenſe he ſeems inclined to think (*ut videtur*, ſays he) that it was admitted by, at leaſt, ſome few people in the Eaſt; beſides the *Jews*, though neither by the *Greeks*, nor *Romans*. From his diffident manner of ſpeaking, however, we may collect, I think, that he was not quite ſatisfied of that opinion, as having but little proof of it; and, indeed, there ſeems to be none at all.

III. As a period of *ſeven* days, in uſe among the Mathematicians, or Aſtrologers, and the like; but not by any public or civil inſtitution.

And in this ſenſe the uſe of the word ἑβδομάδος, in the time of *Joſephus*, was not only well known among the people with whom he was acquainted, but, perhaps, among others too, and that for *many ages* before.

The cuſtom, it may be, began by obſerving the courſe of the Moon, who finiſhes her periodical revolution in 28 days. But $4 \times 7 = 28$; and therefore the whole periodical time of the Moon, divided into four equal parts, gives ſeven days a-piece for each of thoſe parts.

What time the days of the week began to be called by the names of the *ſeven Planets*, is another enquiry.

St. *Auguſtine*, who died A. D. 430, ſays *, *Feria quarta, qui* Mercurii dies *dicitur à* Paganis, *& à multis* Chriſtianis. In his time, therefore, the cuſtom of calling the days of the week, by theſe appellations, was not univerſally admitted among the Chriſtians.

Dies Solis is mentioned in a reſcript of *Conſtantine the Great*, and this prince died A. D. 337.

Dion Caſſius, the Hiſtorian, who flouriſhed about A. D. 210, ſays, Τὸ δὲ δὴ εἰς τὰς ἀςέρας τὰς ἑπτὰ, τὰς ΠΛΑΝΗΤΑΣ ὠνομασμένας, τὰς ἡμέρας ἀνακεῖσθαι, καλέςη μὲν ὑπ' Αἰγυπτίων. πάρεςι δὲ καὶ ἐπὶ πάντας ἀνθρώπους, ἃ πάλαι ποτὲ, ὡς λόγῳ εἰπεῖν, ἀρξάμενον. Οἱ γοῦν ἀρχαῖοι Ελληνες ὐδαμῆ αὐτὸ, ὅσα γε ἐμὲ εἰδέναι, ἠπίςαντο. *The referring of days to the* ſeven Stars, *called* Planets, *was an invention of the* Egyptians. *It is now in uſe among ſt all mankind, but began, as I may ſay, not long ago. 'Tis certain, that, to the beſt of my knowledge, the* ancient Greeks *knew nothing at all of it.*

How long before his time the practice began among the *Egyptians*, he hath not told us; but that the *ancient Greeks*, as he calls them, knew nothing of it, ſeems to be true enough. Mr. *Selden*, indeed †, cites an

* In his Comment on the Title of Pſalm xciii.

† De Jure Nat. & Gent. lib. iii. cap. 19.

old

old oracle of *Apollo* from *Euſebius*, where is made expreſs mention of Ηελίῳ ἡμέρα, *Sunday*, and Μήνης ἡμέρα, *Monday*. But there was ſcarce any thing which the ancients, both Heathens and Chriſtians, were more deceived in, than in the *antiquity* of theſe forged oracles.

Mr. *Selden*, in the ſame place, cites an ancient Greek MS. where it is ſaid, Οι περί Ζωροάςρην καὶ Υςάσπην Χαλδαῖοι, καὶ Αιγύπλιοι ἀπ' ἀριθμῶ τῶν Πλανητῶν, ἐν Εβδομάδι τὰς ἡμέρας ἀνέλαβον. *The* Chaldeans, *that follow* Zoroaſter *and* Hyſtaſpes *and the* Egyptians, *gave the names of the* Planets *to the* days of the week.

This quotation Mr. *Selden* had from *And. Rivetus* *; but what authority the Greek author is of, from whom it is taken, is uncertain. So likewiſe is the age of *Zoroaſter*, and every thing that is ſaid of him. How *Chaldeans* and *Egyptians*, very diſtant nations, come here to be joined with *Zoroaſter* and *Hyſtaſpes*, who are ſuppoſed to be *Perſians*, is hard to ſay, and ſeems to imply what little credit is to be given to the manuſcript from whence this quotation is taken.

In *Æſchylus's Thebaid* † there is this paſſage.

Καλῶς ἔχει τὰ πλεῖς' ἐν ἕξ πυλώμασι
Τὰς δ' ἑβδόμας ὁ σεμνὸς Εβδομαγέτας
Αναξ Απόλλων εἵλετ'----------

Bene habent plurima in ſex portis quidem,
Septimam vero reverendus ſeptimæ (diei) *præfectus,*
Rex Apollo occupavit.---------

The word *diei* is added by the Tranſlator, by way of explication; and from thence it would ſeem as if the days compoſing each month were divided into *ſeptenaries* in the time of *Æſchylus*, who was born about the year before Chriſt 512, according to *Petavius*.

But the Scholiaſt there ſays he was called Εβδομαγέλας, becauſe ἐν ἑβδόμῃ ἡμέρᾳ τοῦ μηνὸς γεννηθεὶς, *he was born on the ſeventh day of the month*. And *Plutarch* ſays ‡, *Apollo* was born on the ſeventh day of the month *Puſius*.

But whether this is to be looked upon as Mythology, or real Hiſtory, is uncertain, as well as, if it be Mythology, what is to be underſtood by it.

It ſeems not improbable, that as by *Apollo* we are frequently to underſtand the Sun, ſo he is here ſtiled by the epithet Εβδομαγέλας, as ruling or preſiding over the *ſeven Planets*. For *Æſchylus* being contemporary with *Plato* and *Eudoxus*, who, it is ſaid, firſt brought the *Greeks* ac-

* Diſſert. de Orig. Sabbat. c. 5. † Ver. 805. ‡ Quæſt. Græc. p. 292.

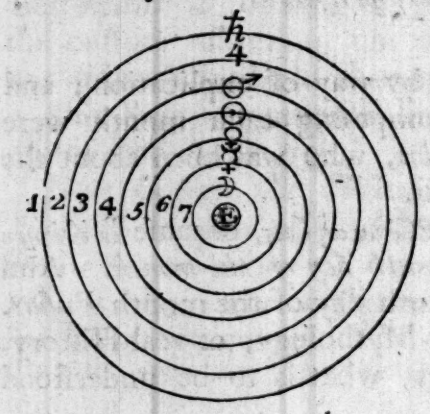
 quainted

quainted with the planetary motions, which they learned in *Egypt*, he might be willing to give a hint of his aſtronomical learning. *Euripides* did the ſame, as we learn from *Diogenes Laertius* in his life of *Anaxagoras*. And *Euripides* was born the year before Chriſt 480; and therefore was but about 30 years younger than *Æſchylus*, who was a very old man when he died.

Juſtin Martyr, who flouriſhed about A. D. 155, mentions Ηλίυ ἡμέραν, *Sunday*, and calls the day on which Chriſt was crucified τὴν πρὸ τῆς Κρονικῆς, the day before *Saturday*; not chuſing perhaps, from ſome ſcruple or other, to call it τὴν τῆς Αφροδίτης. For one part of the accuſation brought againſt the Chriſtians, by their enemies, was, lewd and inceſtuous practices in their aſſemblies, as appears from the ancient Apologiſts.

This, perhaps, is the earlieſt mention of the days of the week being called by the names of the Planets that is any where to be met with. The method itſelf, it is likely, began in *Egypt*, as we learned from *Dion Caſſius* above. For it doth not ſeem probable, that the Chriſtians ſhould give their days the names of heatheniſh divinities. But when the Heathens had given theſe names already, and they began to be in vulgar uſe, they might think it a needleſs ſcrupuloſity not to comply with the cuſtom.

Why theſe names in particular were given to the days of the week, and in this order, will appear, by conſidering the order of the Planets in *Ptolemy*'s, that is, the vulgar, Syſtem.



Here, if we ſuppoſe the Earth to be placed in the middle of the Syſtem, at E, and the Planets diſpoſed in *Ptolemy*'s order, as here; then ſuppoſing *Saturn* to govern the firſt hour of *Saturday*, we ſhall find, by counting according to the order of the Planets, that the 24th hour will fall to the ſhare of *Mars*. The firſt hour of the next day, therefore, will belong to the Sun, who, therefore, will *govern* that hour, and give name to the day, which, conſequently, will be called SUNDAY.

In the ſame manner, by counting on, we ſhall find the 24th hour of this day will belong to *Mercury*. The firſt hour of the next day will, conſequently, belong to the Moon, who will, therefore, *govern* that hour, and from whom that day will be ſtiled MONDAY.

So likewiſe the firſt hour of the next day will be found to be *governed* by *Mars*, from whom the day itſelf will be ſtiled DIES MARTIS; and ſo of the reſt.

It

It was obſerved before, at the beginning of this period, that few improvements in Geography, or Aſtronomy, were to be expected under it.

How long *Alexandria* continued to be a place of learning, is not certainly known; but in the year after Chriſt 365, *Theon* obſerved there an Eclipſe of the Sun. This, with another Eclipſe of the ſame, obſerved by *Thius* at *Athens*, in the year after Chriſt 500, are the chief, if not the only obſervations of this kind to be met with among the *Greeks*. What would be found, ſuppoſing the ſeveral great libraries of *Europe* were carefully ſearched, is hard to ſay. The catalogues of the manuſcripts they contain, it is to be feared, are very imperfect; that of the *Bodlean* library in *Oxford* is certainly ſo.

In the mean time, whatever elſe remains of this ſort, muſt be ſought for, before the revival of learning in *Europe*, in the

ASTRONOMY OF THE ARABIANS.

In the diviſion of the *Roman* empire, *Egypt* fell to the ſhare of the Eaſtern emperors; and under them it continued till the fifth year of *Heraclius*, or A. D. 614. when it was taken from him by *Coſroes* and his *Perſians* *.

If it was aftewards recovered by *Heraclius*, it did not continue long ſubject to the *Greeks*; for under the caliphat of *Omar*, which began A. D. 634, *Amrou Ebno'l-Aas* took *Alexandria*, and burned all the books that had been ſo many years collecting in that famous library. That their number muſt have been prodigious, is certain, if *Abulfaragius* ſays true †, that they ſerved for *heating the public baths for ſix months*.

This ſeems to have put an end to literature in *Egypt*; for the *Arab* princes, for many years, had neither taſte nor leiſure to cultivate the Sciences. At laſt, however, by the encouragement of *Al Maimon*, the ſeventh caliph of *Babylon*, about A. D. 813, the *Arabians* began to apply themſelves to the Sciences, Aſtronomy in particular.

Under this prince lived one *Habaſh*, who compoſed three ſorts of aſtronomical tables. The firſt was compoſed, according to *Abulfaragius* ‡, *ad regulas* Send Hend. This, as the name ſeems to import, might have been ſome *Indian* treatiſe; but theſe, probably, he found not to agree with the Heavens. He, therefore, compoſed another ſet of tables, called *Al Momtachen*, or *the Approved*, as agreeing better with the Heavens; but whether theſe were formed from any obſervations of his own,

* Abulfarag. Hiſt. Dynaſt. p. 99. † Ibid. p. 114. ‡ Ibid. p. 161.

or thoſe of his contemporaries, is uncertain. They might be nothing more than a tranſlation of *Ptolemy*'s, as his Syſtem, it is well known, was the only one followed by them. The third ſort were called *Al Shah*, or *the Royal*, being compoſed, perhaps, for the prince's uſe, and ſeem to have been nothing more than a compendium of the other.

As there was no Aſtronomy extant but *Ptolemy*'s, they got his *Syntaxis* tranſlated into their language; and this they ſeem to have ſtrictly adhered to ever after, and made it their ſole ſtudy, as if nothing in Aſtronomy was to be expected beyond it.

Hence it is that, beſides comments on this work of his, we find but little properly their own, till

AL BATEGNIUS,

as he is commonly called, obſerved, at *Arrecca* in *Meſopotamia*, the *vernal* and *autumnal Equinoxes*, the year after Chriſt 882.

He is called by Dr. *Halley* *, *vir admirandi acuminis, ac in adminiſtrandis obſervationibus exercitatiſſimus*. He wrote a treatiſe, *De Scientia Stellarum*, in Arabic, which was never publiſhed. It was tranſlated into very barbarous Latin by *Plato Tiburtinus*, and publiſhed firſt at *Norinberg*, A. D. 1537, and afterwards at *Bononia*, with notes by *Regiomontanus*, A. D. 1645. There are great differences between the two editions, and great errors in both, which Dr. *Halley* hath corrected in the diſſertation above referred to. After him

EBN YOUNIS

obſerved, in company with others, three Eccliplſes, at *Grand Cairo* in *Egypt*.

1ſt, A Solar Eclipſe, A. D. 977.
2d, A Solar Eclipſe, A. D. 978.
3d, A Lunar Eclipſe, A. D. 979.

That part of the author's manuſcript, which contains theſe obſervations, is now in the public library at *Leyden*.

* Philoſ. Tranſact. No. 204.

AL SUPHI,

ALSUPHI,

who died A. D. 986, compoſed a catalogue of the fixed Stars; but as it is not ſaid that he obſerved them with inſtruments himſelf, this catalogue is, probably, nothing more than *Ptolemy*'s, fitted to his own time, by an allowance for the *Preceſſion of the Equinox*.

From this time till that of *Tycho Brahe*, the noble *Daniſh Aſtronomer*, A. D. 1572. there were few, if any, obſervations made, *i. e.* during an interval of near 600 years.

If any were made, they muſt chiefly be ſought for among the *Arabians*, as this was the dark age of learning in *Europe*.

Under this head of the *Arabians*, we muſt not omit to take notice of one conſiderable improvement made in Arithmetic, and therefore an improvement not only in mercantile buſineſs, but likewiſe in all branches of mixed Mathematics, and particularly in Aſtronomy. This was by the introduction of

THE INDIAN FIGURES.

They are ſuppoſed to have been brought into *Europe* by the *Moors*, or that branch of the *Arabs* that conquered *Spain*.

What time the *Arabs* became firſt acquainted with them, is uncertain. But *Ebn Sina*, commonly called *Avicenna*, who died A. D. 1036, ſays, that "his father ſent him to an herb-merchant to learn them *."

This is the earlieſt mention that we find of them among that people; and perhaps they had not been introduced among them much before this, at leaſt in the common tranſactions of buſineſs. From an Egyptian Calendar, however, in *Montfaucon*'s Supplement to his Antiquities †, it ſeems as if they were known in *Egypt* long before this; for there are plainly to be ſeen on it the figures 443. 112. 431. The antiquity of this Calendar is uncertain, but it ſeems to have been made after *Egypt* was conquered by the *Romans*. Theſe figures did not come into *England*, it ſeems, till about 100 years after *Avicenna*; at leaſt, as far as appears, they were not vulgarly uſed earlier than this. The firſt inſtance that hath been diſcovered of them here, is that mentioned by Dr. *Wallis* in his Algebra ‡, where he ſpeaks of a chimney-piece that he ſaw at *Helmdon* in *Northamptonſhire*, on which were mixed the Roman and Arabic figures M°133, for the date 1133.

* Abulfarag. Hiſt. Dyn. p. 349. † Vol. ii. p. 196. ‡ Cap. 4.

Some

Some perſons, indeed, have thought that they have diſcovered dates in *Arabic* figures older than this at *Helmdon*, but, upon better examination, they have appeared to have been not ſo old. This, Mr. *Ward*, Profeſſor of Rhetoric at *Greſham* College, ſays is the oldeſt that he ever ſaw †.

As the Indian figures are of infinite ſervice in all the branches of mixed Mathematics, and particularly in Aſtronomy, ſo we may obſerve, in this place, that the next conſiderable improvement in this Science was by the introduction of

DECIMAL ARITHMETIC.

This, according to Dr. *Wallis*, in his Preface to his Algebra, as far as appears, was firſt done by *Regiomontanus*, about the year 1450.

But the greateſt improvement of all was made by the introduction of

LOGARITHMS.

For, by their means, numbers almoſt infinite, and ſuch as are otherwiſe impracticable, are managed with eaſe and expedition. They are the inconteſtable invention of the Lord *Neper*, a *Scotchman*, about the year 1614.

Having mentioned the *Arabians*, and their obſervations, we may now proceed to add, that that light which we enjoy between day-break and the riſing of the Sun in the morning, and again between Sun-ſet in the evening and night, is called the

CREPUSCULUM, OR TWILIGHT.

And the firſt perſon that wrote any thing upon this, as far as is known at leaſt, is

ALHAZEN,

an *Arabic* author, who lived about A. D. 1080.

As the beginning of night, and day-break, are terms very indefinite, it may be obſerved, that this Crepuſculum is ſuppoſed to begin in the morning, when Stars of the ſixth magnitude diſappear; and to end in the evening, when Stars of the ſame magnitude begin to appear: and this again is ſuppoſed to be when the Sun is depreſſed 18° in the perpendicular

† Philoſoph. Tranſact. No. 474.

below

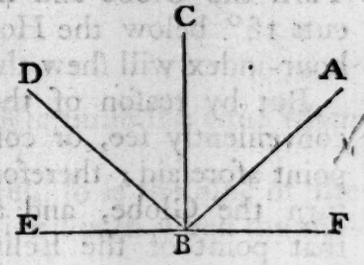
below the Horizon. From which ſuppoſition we may proceed to find the height of our Atmoſphere.

But firſt we muſt premiſe the following

LEMMA.

A ray of light falling upon any ſurface, and reflected from it, makes with the perpendicular the Angle of Incidence equal to the Angle of Reflection.

Thus, let AB be a ray of light falling upon the ſurface EF at B, where let the perpendicular BC be erected. The Angle of Incidence ABC will be equal to the Angle of Refraction DBC.



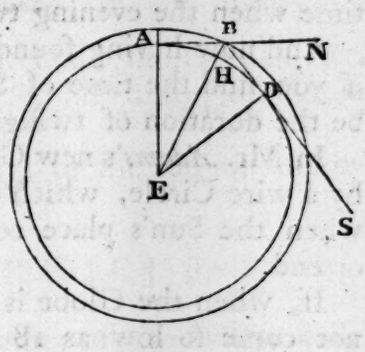
This is a phenomenon, and proved by experiment *.

And now for the

PROBLEM.

Let the Sun be depreſſed 18° below the Horizon, and let a ray of light S B, coming from the Sun, (S) fall upon the top of the Atmoſphere at B, and be reflected to the eye of the obſerver at A, making, with the perpendicular EB, the Angle of Incidence EBD equal to the Angle of Reflection EBA. But SBN being = 18° ABD will be 162° and the half of this, ABE = 81° whence AEB = 9°

Make the Radius AE = 10000000; then HB, the exceſs of the Secant above the Radius, will be = 124651.



Make the ſemidiameter of the Earth AE, in round numbers, = 4000 miles; and then it will be

10000000 : 124651 : : 4000 : $49{,}78^{m}$ = HB,

the height of the Atmoſphere.

And from hence we gain the following

* See Graveſande, and other writers on Natural Philoſophy.

PROBLEM.

Suppoſing the twilight to begin or end when the Sun is depreſſed 18° below the Horizon, the Latitude of the place, and the Sun's place, being given, it is required to find, by the Globe, the beginning and end of twilight.

Rectify the Globe for the Latitude, the Zenith, and the Sun's place. Turn the Globe and the Quadrant of Altitude, until the Sun's place cuts 18° below the Horizon (if the Quadrant reaches ſo far) then the hour-index will ſhew the beginning, or end of twilight.

But by reaſon of the thickneſs of the wooden Horizon we cannot conveniently ſee, or compute, when the Sun's place is brought to the point aforeſaid; therefore, the Globe being rectified, as above directed, turn the Globe, and alſo the Quadrant of Altitude, weſtward, until that point of the Ecliptic which is oppoſite to the Sun's place cuts the Quadrant in the 18th degree above the Horizon; then the hour-index will ſhew the time when day breaks in the morning, or the beginning of twilight.

And if you turn the Globe, and the Quadrant of Altitude, until the point oppoſite to the Sun's place cuts the Quadrant in the 18th degree above the Horizon in the eaſtern Hemiſphere, the hour-index will ſhew when twilight ends in the evening.

Or having found the time from midnight when the morning twilight begins, if you reckon ſo many hours before midnight, it will give the time when the evening twilight ends.

And now having found the time when twilight begins in the morning, if you find the time of Sun-riſing, as before taught, the difference will be the duration of twilight.

In Mr. *Adams*'s new Globes this trouble and inconvenience is remedied by a wire Circle, which is fixed at 18 degrees below the Horizon. For when the Sun's place comes down to that Circle, twilight will begin or end.

If, when the Globe is rectified for any Latitude, the Sun's place doth not come ſo low as 18 degrees below the Horizon, there will be no night there.

In about Latitude 49° on the day of the Summer Solſtice, the Sun's place juſt comes down 18° below the Horizon, and conſequently there twilight ceaſes to be.

In

In Latitudes nearer and nearer the Pole, the twilights will be of longer and longer duration, till in Latitude 66° ½ there will be no twilight but all day; the Sun, when loweſt, only touching the edge of the Horizon.

As the Sun ſets more obliquely at ſome times of the year than at others, and conſequently is longer in deſcending 18 degrees below the Horizon at one ſeaſon than another, it will follow that the length of the twilights will be greater at one ſeaſon than another.

And hence ariſes the following

PROBLEM.

The Latitude of the place being given, to determine the time when the twilight there will be the ſhorteſt poſſible.

Say, as Radius to the Tangent of *nine* degrees, ſo is the Sine of the place's Latitude to the Sine of the Sun's declination South when the twilight is the ſhorteſt poſſible.

Or, becauſe Radius and the tangent of nine degrees are conſtant quantities, it will be the ſame thing as adding the conſtant Logarithm 9.1997125 to the logarithmic Sine of the place's Latitude.

EXAMPLE.

Let the Latitude of the place be 51° 28′ Log. Sin. -	9.8933433
Add the conſtant Logarithm - - - -	9.1997125
Sine of the Sun's declination South 7° 7′ Log. - -	9.0930558

But the Sun hath this declination *March* the ſecond; therefore in Latitude 51° 28′ the twilight is ſhorteſt *March* the ſecond, and again *October* the eleventh.

The demonſtration of this Propoſition belongs to the *maxima* and *minima* of quantities *.

NICHOLAUS COPERNICUS

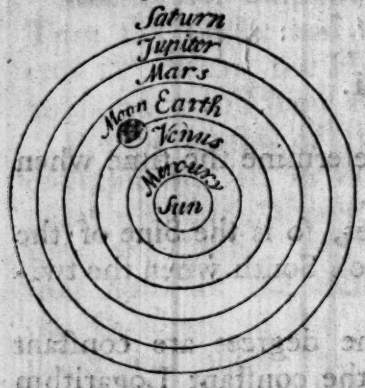
flouriſhed about the year 1530, and was the author of the Syſtem called by his name, and now deſervedly admitted as the only true one.

It is framed out of ſeveral Syſtems, mentioned above.

* See L'Hoſpit. Infinitim. petit. Sect. iii. Prop. 13.

With *Philolaus*, he placed the Sun in the center of the Syſtem; and as the *Sun* had been placed before by *Plato*, *Ariſtotle*, &c. between *Venus* and *Mars*, he removed the *Earth* into its place, and aſſigned it a diurnal motion about its own axis, as *Hicetas* the *Syracuſan* had done before. And whereas *Philolaus* had made the Sun the center of the Moon's motion, he agreed with the reſt of the Philoſophers in continuing to make the Earth the center of her motion.

The Syſtem, therefore, as far as hitherto diſcovered, is as under.



No regard is here had to the proportions of the ſeveral orbits to each other, that being reſerved till we come to ſhew how the *relative* diſtances of the Planets, and thence their true diſtances, are diſcovered.

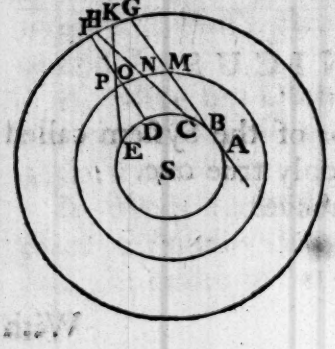
When *Copernicus* propoſed his Syſtem to the World, it was objected to him, that if the poſition of the Planets was ſuch as he ſuppoſed them to be, then *Venus* muſt ſometimes appear horned like the Moon, which, in thoſe days, could not be perceived.

His anſwer was, that, *perhaps*, poſterity would diſcover ſhe really was ſo. And this was verified afterwards, as we ſhall ſee, by *Galileo*, the famous *Italian* Philoſopher.

The Orbits of *Saturn*, *Jupiter*, and *Mars*, including the Orbit of the Earth, they are called the *ſuperior* Planets.

The Orbits of *Venus* and *Mercury*, being included by the Orbit of the Earth, they are called the *inferior* Planets.

This poſition of the heavenly bodies, *Copernicus* ſays, explains all the phenomena of their motions, and gives not only the order of their Orbits, but their magnitudes likewiſe. We ſhall now, likewiſe, be able to account for a phenomenon that greatly perplexed the ancients, *i. e.* the *Stations* and *Retrogradations* of the Planets.



Let ABCD be the Orbit of the Earth, GKHI the Orb of fixed Stars, M a Planet, MBA a line drawn through the Planet, touching the Orbit of the Earth.

When the Earth is at B, let the Planet be at M, and at reſt, it will appear among the fixed Stars at G. While the Earth deſcribes the arch BC, let the Planet deſcribe the arch MN. When the Earth arrives at C, the Planet will be at N, and

and appear among the fixed Stars at H. When the Planet arrives at O, the Earth will overtake it, and, being at D, will ſee the Planet among the fixed Stars at I, having moved from G to I, the *ſame way* with the Earth. This motion is called *direct*.

But while the Planet moves from O to P, the Earth moving faſter, will arrive at E, and the line EP, paſſing through the centers of the Earth and Planet, will meet the Orb of fixed Stars in K; and the Planet will appear to have gone *backwards* from I to K. This motion is called *retrograde*.

While the Earth deſcribed the arch AB, coinciding with the Tangent, the Planet, moving the ſame way, but ſlower, would deſcribe a very ſmall arch in its Orbit; but, by reaſon of the immenſe diſtance of the fixed Stars, the line joining the centers of the Earth and Planet, during this time, would ſtill be ſeen as falling among the fixed Stars at G, and the Planet would ſeem to ſtand ſtill. It is then ſaid to be *ſtationary*.

LIGHT REFRACTED.

As, under the ſucceeding period, we ſhall have occaſion to take notice of ſeveral phenomena, ariſing from the *refraction* of the rays of light, it will be proper to obſeve, in this place, that that if any body be ſo conſtituted as to yield a paſſage to the rays of light, it is called

A MEDIUM.

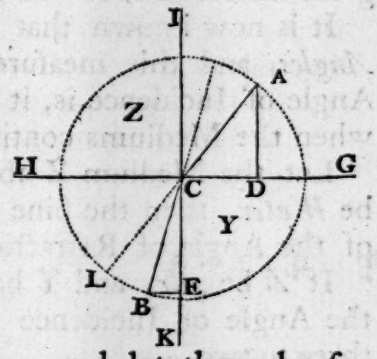
Air, water, glaſs, diamonds, and even a *Vacuum*, are all of them *Mediums*.

If any Medium affords an eaſy paſſage to the rays of light, it is ſaid to be

A RARE MEDIUM.

But if it doth not yield an eaſy paſſage to the rays of light, it is then ſtiled

A DENSE MEDIUM.



Let Z be a *Rare Medium*, and Y a *Denſe* one; and let them be ſeparated by the plane ſurface GH. Let IK be a perpendicular to it, and cutting it in C.

With

With the center C, and any diſtance, let there be a Circle deſcribed. Then let AC be a ray of light falling upon the plane ſurface at C. This ray, if nothing prevented it, would go ſtrait forward to L. But becauſe the medium Y is ſuppoſed to be *denſer* than Z, it will be bent downward towards the perpendicular IK, and deſcribe the line CB.

The Ray AC is called the *Incident Ray*, and the Ray CB is called the *Refracted Ray*.

The Angle ACI is called the *Angle of Incidence*, and the Angle BCK is called the *Angle of Refraction*.

If from the point A, upon the right line GH, there be let fall the perpendicular AD, that line AD is called the *Sine of the Angle of Incidence*.

In the ſame manner, if from the point B, upon the right line IK, there be let fall the perpendicular BE, that line BE will be the *Sine of the Angle of Refraction*.

This property of the rays of light, that they are bent by falling upon Water, a medium of greater denſity than Air, was a phenomenon known to the ancients. For one of *Ariſtotle*'s Problems is concerning the apparent curvity of an *Oar* in the *Water*. And *Archimedes* is ſaid to have wrote a treatiſe concerning a *Ring* ſeen under *Water*.

But the firſt perſon, at leaſt that is known, who wrote expreſsly concerning the laws of Refraction, was *Al Hazen*, an Arabic author, mentioned above.

He makes the meaſure of Refractions to be the Angles themſelves. And in this he was followed by *Vitellio*, who lived and wrote about A. D. 1270. Though this proportion doth well enough in ſmall Angles, where the Sines and the Arches differ inſenſibly, yet in Rays that have pretty great inclination, it will not hold good.

It is now known that the meaſure of *Refractions* is the Sines of the *Angles*, and this meaſure is *conſtant*; that is, whatever the Sine of the Angle of Incidence is, it will be to the Sine of the Angle of Refraction, when the Mediums continue the ſame, in a conſtant proportion.

Let the Medium Z above, for example, be *Air*, and the Medium Y be *Water*, then the Sine of the Angle of Incidence will be to the Sine of the Angle of Refraction as four to three.

If Z be *Air*, and Y be *Glaſs*, then, in round numbers, the Sine of the Angle of Incidence is to the Sine of the Angle of Refraction as three to two.

Examples of Rays paſſing out of *Air* into *Water*, and their Refractions, we have in Rays coming from the Sun, Moon, and fixed Stars, and paſſing through the Atmoſphere to our eyes.

Such

Such Rays as theſe paſſing out of a *rarer* Medium into a *denſer*, from what hath been ſaid, appear to be bent *towards* the perpendicular.

Therefore the contrary muſt be true, *i. e.* if Rays paſs out of a *denſer* Medium into a *rarer*, they muſt be bent from the perpendicular. The uſe to be made of this obſervation will appear very ſoon.

Examples of Rays paſſing out of *Air* into *Glaſs*, and again out of *Glaſs* into *Air*, and their *Refractions*, we have in ſuch objects as are viewed through any ſorts of Glaſſes, whether they are *plain*, *convex*, or *concave*, or any how compounded of theſe. Of this ſort are all objects view'd through *Microſcopes*, or *Teleſcopes*. The firſt ſort we are not at all concerned with, as not falling under the preſent deſign. But the laſt we ſhall have occaſion to ſpeak a little farther upon, when we come to *Galileo*, and his diſcoveries.

And this brings us to the moſt important period of Science, that is, the revival of learning in *Europe*. For ſince that time more hath been done towards bringing that of *Aſtronomy*, in particular, to perfection, than in all the former periods put together.

PART VI.

THE HISTORY OF ASTRONOMY, FROM TYCHO BRAHE TO THE PRESENT TIME.

AS the appearance of a *new Star* gave occaſion to *Hipparchus* to compoſe a catalogue of them, ſo it was the appearance of a *new Star* in *Caſſiopea*, A. D. 1572, that made this Daniſh nobleman apply himſelf, with great diligence, to the obſerving the Heavens. He compoſed a catalogue of 777 fixed Stars, all obſerved by himſelf.

His obſervatory was built in the iſland *Ween*, in Longitude 50′ to the Eaſt of *London* in time, and in Latitude 55° 54′ 30″ North, and was called *Uraniburgh*.

The firſt writer on *Refractions*, we have ſeen, was *Al Hazen*; but the firſt perſon that compoſed a table of *Refractions*, was *Tycho Brahe*, who, likewiſe, firſt ſhewed the uſe to be make of them in Aſtronomy. What that uſe is, will be ſeen preſently.

In the mean while it may not be improper to obſerve, that *Tycho*'s table of Refractions muſt not be looked upon as *univerſal*, or as equally ſerving for all Latitudes. For Refractions are not the *ſame* in *all Latitudes*;---nor at all ſeaſons of the year are they the *ſame* in the *ſame Latitude*;---nor the *ſame* in the *ſame Latitude*, at the *ſame ſeaſon* of the year, every hour of the day.

Bodies,

Bodies, as the Sun, Moon, and Stars, ſuffer the greateſt Refractions when lying in the Horizon of any place. But horizontal Refractions at the Equator are near one-third part leſs than at *Paris* *.

Tycho's table of Refraction, therefore, though it might ſerve very accurately for *Uraniburgh*, yet may not be ſo proper for the Latitude of *London*. It will be beſt, therefore, to make uſe of that compoſed by Dr. *Halley*, or that of Sir *Iſaac Newton*, or Dr. *Bradley*'s †.

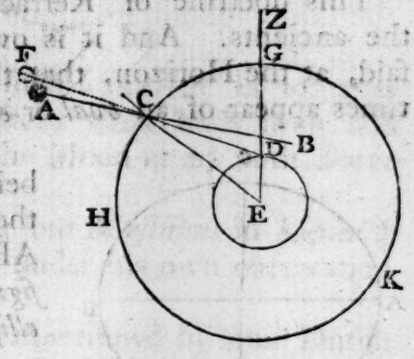
By all theſe tables it appears, that the quantity of Refraction of the Sun, Moon, and Stars, is different at different Altitudes, and that at 60° (according to Sir *Iſaac Newton*) it amounts to no more than 31″; Dr. *Bradley* makes it 33″. The difference is not worth regarding.

What uſe is to be made of ſuch tables of Refractions, will appear by the following Example.

But firſt it will be neceſſary to premiſe the following

PROPOSITION IX.

By Refraction the apparent height of the Sun, Moon, or Stars, above the Horizon, is increaſed.



Let E be the center of the Earth, D any place on the ſurface of it, Z the Zenith of it, CGKH a great Circle in the Atmoſphere, where its *refractive power* begins, CE the Radius of it.

Let A be any Star, and AC a ray of light proceeding from it, and falling upon the Atmoſphere at C. If the Atmoſphere had no *refractive power*, that Ray, after entering the Atmoſphere, would proceed ſtrait forward, *in infinitum*, in the right line CB.

But becauſe that Ray proceeds out of a *rarer* Medium into a *denſer*, it is refracted, or bent towards the perpendicular, or the Radius CE, in the direction CD, and enters the eye of the ſpectator at D.

But the line CD produced *backwards*, meets with the fixed Stars in F; therefore the apparent place of the Star A, to a ſpectator at D, is at F: but the point F is nearer to the Vertex, or Zenith Z, than A. And therefore, by Refraction, the apparent height of the Star above the Horizon is increaſed. W. W. D.

* See Smith's Optics, Remark 370. Mouvem. Celeſt. pour l'Ann. 1765.

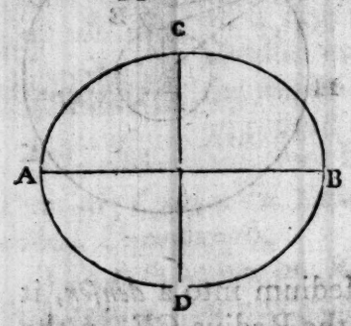
† See Ferguſ. Aſtron. §. 182. and the Connoiſ. des

We now come to the uſe of a table of Refractions.

Father *Gaubil*, a *Jeſuit*, at *Pulo Condore* in the *Eaſt-Indies*, or the *Iſle d'Orleans*, as the *French* call it, in the year 1722, *February* 15, found the apparent height of the Sun's upper limb - - - -	60° 30′ 00″
Semidiameter of the Sun ſubtract - - -	16′ 20″
Apparent height of the Sun's center - - -	60° 13′ 40″
Refraction ſubtract - - - - - -	— 34″
	60° 13′ 06″
Sun's parallax add - - - - - -	+ 06″
Correct height of the Sun's center - - -	60° 13′ 12″
The complement of this to 90° or the Sun's Zenith diſtance, is - - - - -	29° 46′ 48″
The Sun's declination for that time ſubtract - -	21° 11′ 34″
Diſtance of the Equator from the Zenith - -	8° 35′ 14″

But this is equal to the Latitude of the place, which, therefore, we have now found to be = 8° 35′ 14″.

This doctrine of Refractions, as before obſerved, was unknown to the ancients. And it is owing to Refraction, which is greateſt, as was ſaid, at the Horizon, that the Sun and Moon, at *riſing* or *ſetting*, ſometimes appear of an *oval* or *elliptical* figure.



For the Sun's horizontal diameter, A B, being not at all affected by *Refraction*, while the vertical Diameter CD is contracted by it, AB will appear longer than CD; that is, the *figure*, or *diſk* of the Sun, will appear to be *elliptical*, or *oval*.

Diodorus Siculus relates as a great wonder, that, in a country he is ſpeaking of, the Sun doth not appear round, ἀλλὰ κίονι τὸν τύπον ἔχειν ἐμφερῆ, μικρὸν ἐμβριθὲς ἕραν ἔχοντι τὴν ἀπὸ τῆς κεφαλῆς ἐπιφανειαν, *but like a pillar, having his upper ſurface a little flatted* *.

This paſſage ſeems to be miſplaced in *Diodorus*. It is plainly borrowed from *Agatharchides*, whom he quotes here, and who was ſpeaking of ſome high northern Latitude, where the day, from Sun-riſe to Sun-ſet, was but three hours long. This, we may ſuppoſe, was in the depth of winter, and will hold good of places that lie in about 65° of Latitude.

* Page 182.

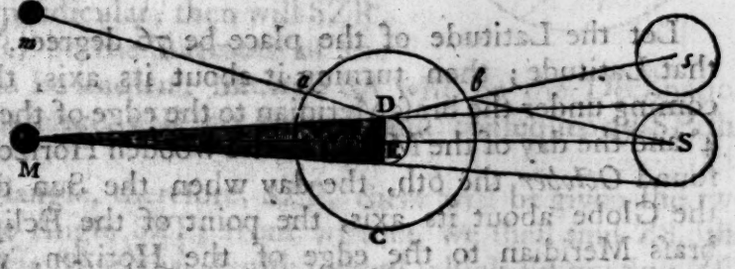
The

The reſt of the account hath the air of fable, ariſing from the ſtrange ſtories brought home by ſailors relating to far diſtant countries. The whole paſſage is curious, and may be greatly cleared up, was this a proper place.

Pliny obſerves *, that the Moon had been eclipſed once in the Weſt above the Horizon, at the ſame time that the Sun appeared above the Horizon in the Eaſt. The ſame phenomenon had been related before by *Cleomedes* †, from whom probably *Pliny* borrowed it. But *Cleomedes* calls it a *fiction*, looking upon it as impoſſible.

For if the Moon (M) is eclipſed by falling into the ſhadow of the Earth (E), which they knew, and therefore that the Sun, at that time, muſt be in the oppoſite part of the Heavens, they concluded, that if the Moon (M) was above the Horizon, the Sun (S) muſt be below it; and therefore that both could not be viſible at the ſame time.

But if *abc* is the upper ſurface of the Atmoſphere of the Earth, and M*a* a Ray falling upon it at *a* from the Moon, and S*b* a Ray coming from the center of the Sun, and falling upon it at *b*; if thoſe Rays are refracted in ſuch a manner as to enter the eye of an obſerver at D, it is plain, from what hath been ſaid before, that the Sun will appear at *s*, and the Moon at *m*, both above the Horizon.



Such ſights as theſe are not very common; but *Mæſtlinus* in *Kepler* ‡ mentions one inſtance of the like which fell under his own obſervation *July* 7, 1590 §.

There is a remarkable inſtance of Refraction mentioned by ſome Dutch ſailors, who wintered at *Spitzberg* in *Nova Zembla*, in Latitude 76° North. For *November* 4, 1596, they loſt ſight of the Sun; and whereas they ought not to have ſeen him again in that Latitude till the next year *January* 30, 1597, they unexpectedly ſaw him *January* 24, or ſix days ſooner than they would have done had there been no Refraction ‖.

This will be beſt explained by the following

* Nat. Hiſt. lib. ii. cap. 13. † Lib. ii. cap. 6. ‡ Aſtron. Part. Optic. p. 136.
§ See another in the Memoirs of the Academy of Sciences for the year 1750, when the Moon roſe eclipſed July the 19th. ‖ See Varen. Geog. vol. ii. p. 116—118.

PROBLEM.

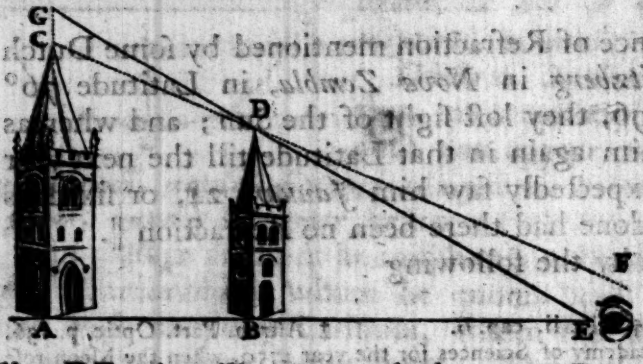
The Latitude of any place within the Arctic Circle being given, to find the day of the month when the Sun first rises and sets.

Rectify the Globe for the Latitude of the place, and turning the Globe about its axis, mark what point of the Ecliptic comes up to the edge of the wooden Horizon, and under the brass Meridian at the same time. Look for that point of the Ecliptic on the wooden Horizon, and oppoſite to it will be found the day of the month. This will be the day of the month when the Sun will appear for the firſt time on the Horizon at noon, and conſequently will begin to riſe and ſet.

EXAMPLE.

Let the Latitude of the place be 76 degrees. Rectify the Globe for that Latitude; then turning it about its axis, the point of the Ecliptic coming under the braſs Meridian to the edge of the Horizon, will be *Scorpio* 4, and the day of the Month on the wooden Horizon anſwering to it will be found *October* the 6th, the day when the Sun diſappears; and turning the Globe about its axis, the point of the Ecliptic coming under the braſs Meridian to the edge of the Horizon, will be found *Aquarius* 27 degrees; the day of the month oppoſite to which on the wooden Horizon will be found *February* the 4th. This will be the day on which the Sun will appear, in that Latitude, for the firſt time at noon.

Refractions in the ſame place are not always of equal quantity. And this is the reaſon why hills and towers, ſituated behind others, ſometimes appear, and ſometimes diſappear.



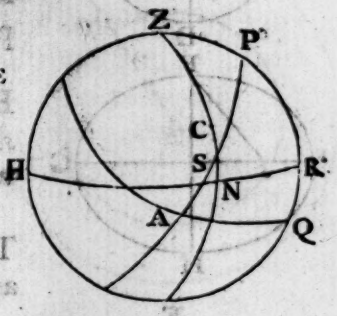
Let there be a tower at B, and another ſtanding behind it at A, and let the eye of the obſerver be at E. The line CDF drawn through C and D, and the tops of the towers, and continued to F, will fall above the obſerver's eye at E. Let the line CD be now bent down, by *Refraction*, into the line DE; it will now reach the eye at E, and continued backwards to G, the top of the tower A will be viſible at G to an eye placed at E.

As

As we have ſeen the nature of Refractions in general, and in what manner the apparent altitudes of the Sun, Moon, and Stars, are affected by them, it will not be improper, in this place, to add the following

PROBLEM.

To find the Refraction of any Star by obſervation.



Let HR be the Horizon of any place, HZPR the Meridian, Z the Zenith, P the Pole; the arch PR will be the height of the Pole above the Horizon, and ZP its complement to 90 degrees.

Let ÆAQ be the Equator, S the Star whoſe Refraction is to be found; and let C be its apparent place in the perpendicular; then will SZR, whoſe meaſure is NR, be the Azimuth of the Star, which ſuppoſe to be known; likewiſe SA will be the Declination of the Star, which therefore will be known, and conſequently SP the complement of it.

In the ſpherical Triangle, therefore, SZP, there will be given the two ſides ZP, SP, and the Angle SZP; from whence we ſhall find ZS, the *true* diſtance of the Star from the Zenith; from which ſubtracting ZC, its *apparent* diſtance, we ſhall have the difference CS, the Refraction of the Star. W. W. F.

We now come to the moſt learned and ſagacious

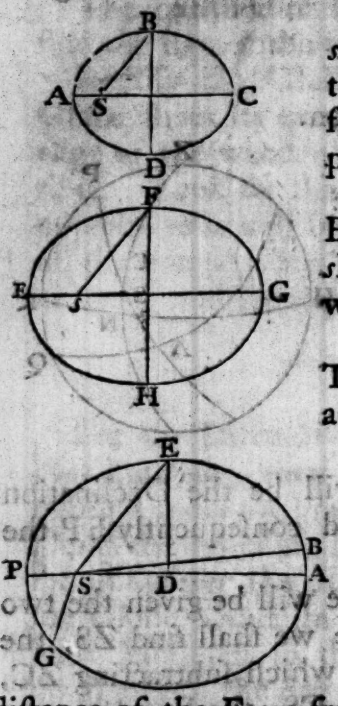
KEPLER,

before whoſe time the World had believed the Orbits of the heavenly bodies to be circular only. But A. D. 1609 he publiſhed his Commentary on the motion of *Mars*, in which he ſhewed, from the obſervations of *Tycho Brahe*, that this Planet deſcribed an *Ellipſis* about the Sun, placed in the lowermoſt focus, and collected the ſame to be the caſe of all the reſt.

This hypotheſis of *Kepler* was oppoſed, and rejected by *moſt* of the Aſtronomers of his time, yet it is now almoſt univerſally acknowledged to be the only *true one*, and by which alone the places of the heavenly bodies can be obtained, agreeing with *obſervations*.

He

He first discovered, likewise, this great law observed by Nature in the revolutions of the heavenly bodies, that the *squares* of their *periodical times* are as the *cubes* of their *mean distances*.



Let ABCD, EFGH, be two *Ellipses*, and S and *s* their *Foci*, in which suppose the Sun to be placed; then SB, *s*F, will be mean distances of the Planets from the Sun. And putting P and p for their periodical times, it will be,

$$P^2 : p^2 :: SB^3 : {}_sF^3$$

But, by the nature of the *Ellipsis*, SB $= \frac{1}{2}$ AC, and ${}_sF = \frac{1}{2}$ EG; therefore, since the halves are as their wholes, it will be,

$$P^2 : p^2 :: AC^3 : EG^3$$

That is, the *squares* of the *periodical times* will be as the *cubes* of the *transverse axes*.

He demonstrated, likewise, that though a Planet at A, where it moves *slowest*, describes a less arch than at P, where it moves *swiftest*, yet that the elliptical areas ASB, PSG, described in *equal times*, are equal.

In this elliptical hypothesis, the point D is called the *Center* of the *Ellipsis*, and SD the distance of the *Focus* from that *Center*, is called the

ECCENTRICITY.

The Eccentricities of the planetary Orbits are different.

If the *mean* distance of the Earth from the Sun SE, or PD, be made = 1000,

The Eccentricity of *Mercury* will be - -	80	of such Parts.
Venus will be - -	5	
the *Earth* will be - -	169	
Mars will be - -	141	
Jupiter will be - -	250	
Saturn will be - -	547	

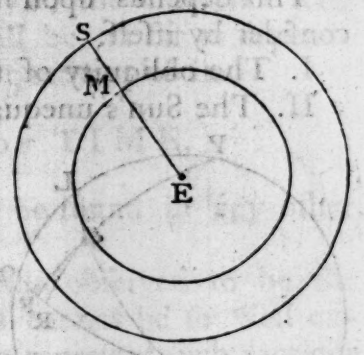
The Eccentricity of the Moon's Orbit is continually changing; but supposing her *mean* distance from the Earth divided into 1000000 Parts,

Her *greatest* Eccentricity is now made about -	66782	of such Parts.
Her *mean* Eccentricity about - - - - -	59727	
Her *least* Eccentricity about - - - - -	43319	

From

From this diſcovery of *Kepler*, that the *ſquares* of the *periodical times* of the Planets are as the *cubes* of their *mean diſtances*, we arrive at a demonſtrative proof that the *Ptolemaic* Syſtem muſt be falſe.

For let E be the Earth, M the Moon, S the Sun, and let both be ſuppoſed to perform their revolutions round the Earth.



Then ſince the Moon performs her period about the Earth in the ſpace of 27 days, in whole numbers, at the diſtance of about 60 ſemidiameters of the Earth, and the Sun finiſhes his apparent courſe about the Earth in 365 days, neglecting the odd hours and minutes, it will be, by *Kepler*'s rule,

$729\ (=\overline{27}^2) : 133225\ (=\overline{365}^2) :: 216000\ (=\overline{60}^3) : 39460356,$

the *Cube Root* of which is 340, which ought to expreſs SE, the diſtance of the Sun from the Earth, in ſemidiameters of the Earth, provided the Sun governs his motion by the ſame law with the reſt of the Planets.

But Aſtronomers prove, by invincible reaſons, that the Sun is above thirty times farther from the Earth than 340 ſemidiameters of the Earth; for it cannot well be ſuppoſed ſo little as 10,000 ſemidiameters. But, according to this diſtance, the periodical courſe of the Sun about the Earth could not be finiſhed in leſs than 54,700 years.

The Earth, therefore, is not the center of the Sun's motion, and conſequently that Syſtem muſt be falſe which ſuppoſes it to be ſo.

Being advanced thus far in the true Syſtem of the World, it becomes neceſſary to obſerve, that time is of two ſorts, *real* and *apparent*.

Real time is that even flux of duration, which is always going on, with a *conſtant uniform tenor*, and depends not on the motion of any body whatever.

Apparent time is duration, as it is diſtinguiſhed by the motion of ſome body or other, and particularly by the revolution of the Sun; that is, it is that ſpace of time which is comprehended between the Sun's leaving the Meridian of a place, and his return to that Meridian again.

But as the motion of the Sun is not equable, and therefore doth not ſhew the *true*, but the *apparent* time only, and as in all aſtronomical computations it is requiſite to have the *true* time, the firſt ſtep to be taken is to reduce the *apparent* time to the *true* or *real*, or, as it is commonly called, the *mean* time. And this gives what is uſually called

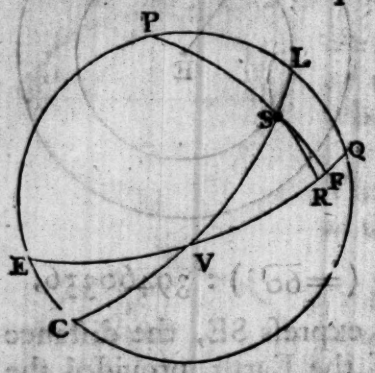
THE

THE EQUATION OF TIME.

This depends upon two cauſes, each of which it will be proper to conſider by itſelf.

I. The obliquity of the Ecliptic.

II. The Sun's unequal motion in the Ecliptic itſelf.



Let EVQ be the Equator, and CVL the Ecliptic, P the Pole of the Equator, and S the place of the Sun, in the firſt quadrant of the Ecliptic.

Let there be ſuppoſed a *fictitious* Sun, moving in the Equator EVQ. And becauſe we at preſent do not conſider the inequality of the Sun's motion, the motion of the *real* Sun and the *fictitious* Sun will be equable; and therefore they will deſcribe the Ecliptic and the Equator in the ſame time, and ſo equal portions of them in equal times.

Therefore, if the *real* Sun and the *fictitious* Sun are ſuppoſed to ſet out together from the vernal Equinox V, when the *real* Sun comes to S, the *fictitious* Sun will arrive at F, having deſcribed the arch VF equal to the arch VS.

At S and F ſtick black patches; then the arch VF will be the *right aſcenſion* of the *fictitious* Sun F.

But if from P, the Pole of the Equator, through S, the place of the *real* Sun in the Ecliptic, there is drawn the great Circle PS, it will cut the Equator in R, and the arch VR will be the *right aſcenſion* of the *real* Sun S.

But the arch VR being leſs than the arch VF, the *right aſcenſion* of the *real* Sun will be leſs than the *right aſcenſion* of the *fictitious* Sun.

But ſuch heavenly bodies as have the *leaſt right aſcenſion* come to the Meridian ſooner than thoſe whoſe *right aſcenſion* is *greater*; and therefore, in this caſe, the *real* Sun will come to the Meridian before the *fictitious* Sun.

The time, as denoted by the motion of the *real* Sun, is that called

APPARENT TIME.

And the time, as denoted by the motion of the *fictitious* Sun, is that called

EQUAL,

EQUAL, OR MEAN TIME.

In this caſe, therefore, the *apparent* time precedes the *mean*. And if the arch VR be ſubtracted out of the arch VF, the difference RF, turned into time by the table already given *, will be, as far as depends on the obliquity of the Ecliptic, and in the firſt quadrant of it,.

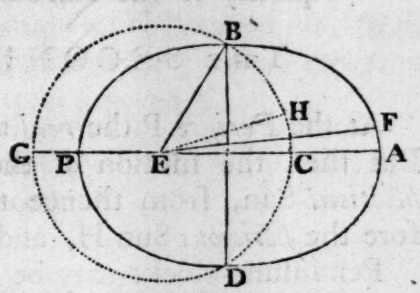
THE FIRST EQUATION OF TIME.

In the ſame manner may the equation of time be found in any other quadrant of the Ecliptic.

The ſecond cauſe of the equation of time, was obſerved to be the Sun's unequal motion in the Ecliptic. But this cannot be ſo well explained on the Globes, which are adapted only to repreſent ſuch motions as are equable.

However, as, before, we conſidered the firſt cauſe, *i. e.* the obliquity of the Ecliptic, and the phenomenon of the Sun's motion in that, independent of the ſecond cauſe, his inequality of motion in it, ſo here we may conſider the ſecond cauſe independent of the former.

Let E be the Earth, and the Ellipſis ABPD the line of the Sun's apparent annual motion round it. Let A be the Sun's *Apogee*, and P his *Perigee*.



With the diſtance EB, the Sun's *mean diſtance* from the Earth, let there be deſcribed the Circle CBGD, and let both be ſuppoſed to lie in the plane of the *Equator*.

While the *real* Sun deſcribes the Ellipſis ABPD, let a *fictitious* Sun, with an equable motion, deſcribe the Circle CBGD. Let the *real* Sun ſet out from A, and the *fictitious* Sun from C, at the ſame time.

The motion of the *fictitious* Sun C, being ſwifter than that of the *real* Sun A, while the *real* Sun A deſcribes the elliptical arch AF, the *fictitious* Sun will deſcribe the circular arch CH.

The time denoted by the motion of the *real* Sun, is, as before, that called

* Page 42.

APPARENT TIME.

And the time denoted by the motion of the *fictitious* Sun is, as before, called

MEAN, OR EQUAL TIME.

During all the time, therefore, that the *real* Sun goes from the *Apogee* A to the *Perigee* P, and the *fictitious* Sun from C to G, *i. e.* during the first six signs of anomaly, the *fictitious* Sun H will be before the *real* Sun F.

In this case, therefore, the *fictitious* Sun H will be more advanced in the Equator than the *real* Sun, or more to the eastward; therefore sticking black patches in those places, and turning the Globe westward, the *right ascension* of the *real* Sun will be seen to be less than the *right ascension* of the *fictitious* Sun, and consequently will come up to the Meridian before it; and, in this case, the *apparent* time will precede the *mean*. The difference, likewise, between the *right ascensions* of the *real* Sun and the *fictitious* Sun, turned into time, as before, will be, as far as depends on the inequality of the Sun's motion in the Ecliptic,

THE SECOND EQUATION OF TIME.

At the *Perigee* P the *real* and *fictitious* Suns come in conjunction again. But then the motion of the *real* Sun being quicker than that of the *fictitious* Sun, from thence to the *Apogee* A, the *real* Sun F will be before the *fictitious* Sun H, and the *mean* time will precede the *apparent*.

Pendulum-clocks may be made to keep pace with the Sun's *mean* motion. And in what manner this may be done, may be seen in the *Connoiss. des Temps* for the year 1759 *.

Contemporary with *Kepler*, last spoken of, or about A. D. 1609, flourished the much celebrated

GALILEO,

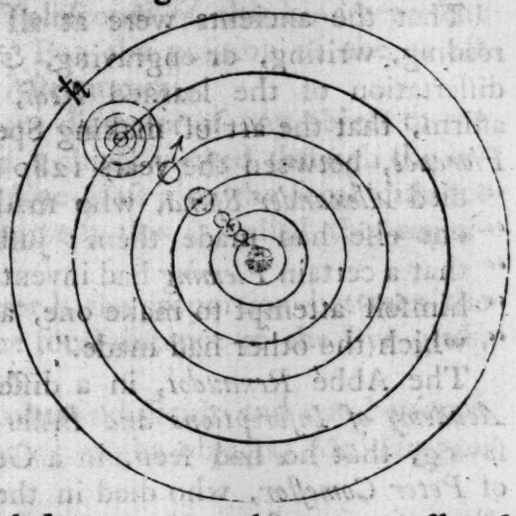
who was the first that applied a Telescope to the Heavens, where he discovered the spots in the Sun, the four Satellites of *Jupiter* (called by him the *Medicean Stars*, in honour of the dukes of *Tuscany*) and *Saturn* to be of a very strange and uncouth figure †.

* Page 165. † See Mr Huygens's System. Saturn. assert.

This

This laſt aroſe from the imperfection of Teleſcopes at that time, and the vaſt diſtance of *Saturn* from the *Sun*, or *Earth*.

The Syſtem of the Planets now became enlarged in this manner.



Galileo obſerved unevenneſſes in the Moon, like hills and vallies; and that the *Milky Way*, and *Nebulæ*, obſerved in ſome parts of the Heavens, as in the head of *Orion*, in *Cancer*, *&c.* are nothing more than a *congeries* of Stars, too ſmall to be ſeen by the naked eye.

That the Moon is inhabited, and hath in it hills and vallies, is ſaid to have been the opinion of *Anaxagoras*, about the year before Chriſt 480, as we ſaw before.

But this could only be matter of conjecture, before the invention of Teleſcopes, or, perhaps, was aſſerted by him, as a conſequence of his other opinion, that the Sun and Moon were material; an opinion that had like to have coſt him his life.

That the *Milky Way* was nothing but a *congeries* of ſmall Stars, ſeems likewiſe to have been ſuſpected by ſome of the ancients, as appears from *Manilius* *, who, after giving the fabulous account, adds,

Anne magis denſa Stellarum turba corona
Contexit flammas, & craſſo lumine candet,
Et fulgore nitet collato clarior Orbis?

Galileo obſerved, by means of his Teleſcope, that *Venus* did appear ſometimes horned like the Moon; and thereby verified the conjecture of *Copernicus*, and ſo far proved that his was the true Syſtem of the World.

He was the firſt perſon that thought of finding the Longitude of places by means of the Eclipſes of *Jupiter*'s Satellites, of which we ſhall ſee more hereafter. In the mean time, it may not be amiſs to add here a word or two concerning the nature of

* Lib. i. ver. 753.

TELESCOPES.

That the ancients were at all acquainted with the uſe of glaſſes in reading, writing, or engraving, *&c.* is far from certain. In *Spon* * is a diſſertation of the learned *Redi*, in which he ſays, he can poſitively affirm, that the art of making Spectacles is new, and was diſcovered at *Florence*, between the years 1280 and 1311. "For this year (he ſays) "died *Alexander Spina*, who made Spectacles, having heard that ſome "one elſe had made them: juſt as, afterwards, *Galileo* having heard "that a certain *Fleming* had invented what are now called Teleſcopes, did "himſelf attempt to make one, and ſucceeded, without ever ſeeing that "which the other had made."

The Abbé *Renaudot*, in a diſſertation, printed in the *Hiſtory of the Academy of Inſcriptions and Belles Lettres* †, quotes father *Mabillon* as ſaying, that he had ſeen, in a German monaſtery, a ſcholaſtic Hiſtory of *Peter Comeſtor*, who died in the beginning of the 13th century; that there, to repreſent *Aſtronomy*, was drawn *Ptolemy* looking at the Stars through a Teleſcope ſuch as ours. But this, as he obſerves, is the more ſurpriſing, as the uſe of *Single Glaſſes* was not diſcovered till about 100 years afterwards.

Whatever there may be in this, the firſt perſon that made a Teleſcope is now generally thought to be one *Johannes Baptiſta Porta*, a *Neapolitan*, about A. D. 1594.

But as the effects of ſuch a combination of Glaſſes, in diſcerning remote objects, was diſcovered by him only by chance, he never conſidered the theory. And though others, after *Porta*'s example, made ſmall Teleſcopes, yet the firſt perſon that made one *tolerably good*, and applied it to obſerving the Heavens, was the perſon we have been laſt ſpeaking of, *Galileo*.

His Teleſcope conſiſted of a *convex* Object-glaſs, and a *concave* Eye-glaſs. Teleſcopes of this kind repreſent far diſtant objects *diſtinct* and *erect*.

In this ſort of Teleſcope the diameter of any object to the naked eye is to the diameter of the ſame object viewed through the inſtrument : : as the focal diſtance of the Concave Glaſs : to the focal diſtance of the Convex Glaſs. And this is called the *magnifying Power*.

* Recher. Curieuſ. d'Antiq. p. 213. † Vol. iv. printed at the Hague.

THE

THE COMMON ASTRONOMICAL TELESCOPE

conſiſts now of two Convex Glaſſes. Teleſcopes of this kind repreſent far diſtant objects *diſtinct*, but *inverted*. But the poſition of the object is a circumſtance not at all regarded by Aſtronomers.

In Teleſcopes of this ſort, the apparent diameter of any object to the naked eye : is to the diameter of the ſame object viewed through the inſtrument : : as the focal diſtance of the Eye-glaſs : to the focal diſtance of the Object-glaſs. And in this inſtrument this is called the *magnifying Power*.

From hence it appears, that the greater is the proportion between the focal diſtance of the Object-glaſs, and the focal diſtance of the Eye-glaſs, the greater will be the *magnifying Power*.

But as the management of very long tubes is difficult and cumberſome, and cloſe tubes are not neceſſary for viewing night objects, Mr. *Huygens* contrived a Teleſcope, called the

AERIAL TELESCOPE.

It is deſcribed in the ſecond volume of his Works, and in the Appendix to *Stone*'s tranſlation of *Bion*'s book of mathematical inſtruments.

Between the years 1666 and 1671, Sir *Iſaac Newton* contrived, and brought to perfection, another ſort of Teleſcope, called the

CATADIOPTRICAL TELESCOPE.

The nature of the inſtrument will be underſtood better by inſpection than by any deſcription whatever.

In this inſtrument, the apparent diameter of any object to the naked eye : is to the diameter of the ſame object viewed through the inſtrument : : the focal diſtance of the Eye-glaſs : is to the focal diſtance of the *Concave Speculum*. And this is called, in this ſort of Teleſcope, the *magnifying Power*.

This kind of Teleſcope, though proper for viewing cœleſtial objects, eſpecially ſuch whoſe altitudes are very great, yet is not ſo well adapted to the viewing terreſtrial objects. Therefore there is another ſort of *Catadioptrical Teleſcope*, called the

GREGORIAN

GREGORIAN TELESCOPE.

It was firſt attempted by Mr. *J. Gregory* at *Aberdeen*, but without ſucceſs.

At laſt *John Hadley*, Eſq; Vice-Preſident of the *Royal Society*, after making the *Newtonian* Reflecting Teleſcopes with good ſucceſs, and improving all *Gregory*'s hints, did at laſt bring the *Gregorian* Teleſcope to perfection, by the work of his own hands; and afterwards taught Mr. *Edward Scarlet*, and his ſon, to do the ſame. This was in the year 1726, and is the Reflecting Teleſcope now in uſe.

Having ſaid thus much concerning the inſtrument, and its inventor, the next thing to be taken notice of, is the application of it, and what farther diſcoveries have been made by it, beſides thoſe already mentioned. For by this means only we ſhall be enabled to judge of what great importance it hath been in the improvement of Aſtronomy.

Amongſt other diſcoveries, then, made by means of the Teleſcope, are certain *ſpots* in the *Sun*, which are found to move from Weſt to Eaſt, and, by whoſe motion, the Sun is diſcovered to *turn* round his own axis in the ſpace of twenty-ſeven days, or, according to later obſervations, in twenty-five days and ſix hours.

By means of theſe ſpots, likewiſe, his axis is found to be inclined to the plane of the Ecliptic, or the plane of the *Earth's annual Orbit*, in an Angle of about 83 degrees.

The moſt exact obſerver of theſe ſpots in the Sun was

CHRISTOPHER SCHEINER,

who publiſhed a treatiſe concerning them A. D. 1626.

Theſe ſpots are ſometimes found to increaſe to a very large ſize, and to laſt for a conſiderable time. There ſeem to be inſtances of two very remarkable ones in *Abulfaragius* *. For he ſays, that "in the 9th year "of *Juſtinian* the ſecond (as he calls him) the Sun ſuffered a diminution "of his light, which laſted above a year and two months; and that, "during that time, *very little* of his light remained." This prince began to reign A. D. 527, therefore his 9th year was A. D. 535. And again he ſays, that "in the 17th year of the emperor *Heraclius* half "the body of the Sun was obſcured; and that this continued from the

* Hiſt. Dynaſt. p. 94—99.

"*firſt*

"*firſt Tiſrin* till *Haziran*;" that is, from *October* till *June*. This prince began to reign A. D. 610, therefore his 17th year was A. D. 626.

As by the motion of the ſpots obſerved on the ſurface of the Sun, as was ſaid, he was diſcovered to turn round his own axis in about 25 days, ſo, by means of the Teleſcope, have ſpots been diſcovered on the ſurface of moſt of the Planets; and by the motion of thoſe ſpots are determined the times of their revolutions about their own axes.

Mercury keeps always ſo near the Sun, and ſhines with ſo bright a luſtre in all his parts, that no *ſpots* have, as yet, been diſcovered on his ſurface. He is therefore only concluded to turn round his axis by parity of reaſon, and from the inconvenience which his inhabitants would otherwiſe undergo. For the light and heat which he receives from the Sun are ſeven times as great as ours, and the Sun appears to him almoſt ſeven times as large as he doth to us.

Saturn, on the other hand, is ſo far removed from us, that, by reaſon of his diſtance, no *ſpots* have, as yet, been diſcerned on his ſurface. He is, however, by the like or greater parity of reaſon, concluded to turn round his axis, that all his parts may enjoy a proper degree of light and warmth from the Sun. For the Sun appears about ninety times leſs to him than he doth to us, and the light and heat he receives from him is ſo much proportionably leſs than ours.

But *Venus*, by means of *ſpots* obſerved in her, is found to turn round her axis in the ſpace of 23 hours, or, according to the later obſervations of ſeignior *Bianchini* at *Rome*, in 24 days eight hours. By the ſame ſpots he likewiſe determines the inclination of her axis to the axis of her Orbit to be 75 degrees, which is the cauſe of many ſingular phenomena in this Planet.

Mars, by the like *ſpots*, is found to turn round his axis in 24 hours and 40 minutes. So that his day and night together are 40 minutes longer than ours.

Jupiter, by the like method, is found to turn round his own axis in the compaſs of nine hours and 56 minutes.

Beſides abundance of ſpots, he hath ſome bands, or girdles, which ſurround him. They are parallel to each other, but preſerve neither the ſame magnitude nor diſtance from each other; but ſometimes they increaſe, and ſometimes diminiſh, their breadth; ſometimes they approach each other, ſometimes they recede from one another, and undergo ſeveral changes.

In the year 1665, M. *Caſſini* diſcovered a very large *ſpot* in *Jupiter*'s diſk, which he obſerved continually for the ſpace of two years. It vaniſhed

vaniſhed in the year 1667, and was not ſeen again till the year 1679. It was ſeen continually for the ſpace of *three* years almoſt, and then diſappeared by degrees. Since that time it hath appeared and diſappeared more than once. In a word, from the year 1665, when it firſt appeared, to the year 1708, it had appeared and diſappeared *eight* times.

Contemporary with *Scheiner* and *Galileo* lived

BAYER,

who, in the year 1603, publiſhed his *Uranometria*, containing *delineations* of the *Aſteriſms*;---diſtinguiſhing the *magnitudes* of the Stars compoſing each Conſtellation, and marking them with *letters* of the *Greek* or *Roman* alphabets. This method is of great uſe in aſtronomical obſervations. For by means of it the path of a Comet amongſt the fixed Stars may not only be traced out with great exactneſs, but likewiſe deſcribed to others.

By this means, likewiſe, may be ſeen, with great eaſe, whether any Stars that were in former catalogues have diſappeared, or if any new ones have appeared, and their places noted.

In the year 1639, *November* the 24th, at *Hool*, a little town about fifteen miles to the North of *Liverpool*, in *Lancaſhire*,

HORROX,

a young clergyman there, ſaw, the firſt perſon of any that ever lived, *Venus* in the *Sun*. This is a ſight ſeldom to be ſeen. It was obſerved again *June* the 6th 1761, by great numbers of Aſtronomers, excited particularly by a diſſertation of Dr. *Halley* in the *Philoſophical Tranſactions* *, in which he propoſed finding, from that tranſit, the *Sun's Parallax*, and thence the *diſtance* of the *Earth* from the *Sun*.

The reſult of thoſe obſervations may be ſeen in the *Connoiſſance des Mouvemens Celeſtes* for the years 1763 and 1764. And by comparing together a great number of obſervations, Mr. *Short*, in a diſſertation on that ſubject †, ſtates the *Sun's Parallax*, on the day of the tranſit, at 8″ 56. And as the reſults ſo nearly coincide, it ſeems to him, he ſays, "impoſſible that the mean of them all can err one-tenth of a ſecond, "and that, probably, the error doth not exceed the one-hundredth part "of the whole quantity, as the great Dr. *Halley* had, many years ſince, "confidently preſaged."

* No. 348. † Page 43.

There

There will be another tranſit of this ſame planet in the year 1769, *June* the 3d, at 10^h 10′, according to Mr. *De la Lande* *, and conſequently inviſible at *Paris* or *London*; but by comparing together two obſervations to be made, one at *Mexico*, and the other to the North of *Peterſburgh*, he ſays †, the *Sun's Parallax* may be determined with double the preciſion it was in the laſt.

RICCIOLI

publiſhed his *Almageſtum Novum* at *Bononia* in *Italy* A. D. 1651.

He was aſſiſted by *Grimaldi*, another *Jeſuit*, whoſe obſervations he frequently mentions, and whoſe *Selenography* he hath inſerted into his *Almageſt*. But the moſt accurate *Selenography* of all, is that publiſhed by *Hevelius*, A. D. 1647, at *Dantzic*.

Riccioli defends the *Ptolemaic* opinion of the Earth's being the center of the Syſtem, by arguments drawn from the authority of the Church, and from Scripture.

But the opinions of Fathers and Councils, in matters purely philoſophical, and where they were no competent judges, may now, in a Proteſtant country eſpecially, be ſafely given up to better information from reaſon and experiments.

And with regard to arguments taken from Scripture, it may be obſerved in general, that it no where ſpeaks of the Earth's immobility, in the ſenſe contended for by the eſpouſers of the *Ptolemaic* Syſtem.

All that ſuch texts of Scripture can be brought to prove is, the general eaſe and ſatisfaction of mind that good men enjoy under the protection of Providence; or that the *natural* World is not left at random, but governed, under the ſupreme Ruler of it, by fixed and ſtated laws. The deſign of Scripture was not to inſtruct men in Philoſophy, which they may acquire by a due uſe of their natural faculties. But though this may ſerve for a general anſwer to all arguments of this kind that can be brought in ſupport of that Syſtem, yet it will not be quite foreign to the purpoſe to take ſome more particular notice of one argument, which was urged by them, from the circumſtance of the *Sun's ſtanding ſtill*, mentioned in the book of *Joſhua* ‡.

This phenomenon, whatever it was, is attended with great difficulties, either upon the *Ptolemaic* or *Copernican* hypotheſis.

* Aſtronom. vol. ii. p. 779. † Ibid. p. 787. ‡ Chap. x. ver. 13.

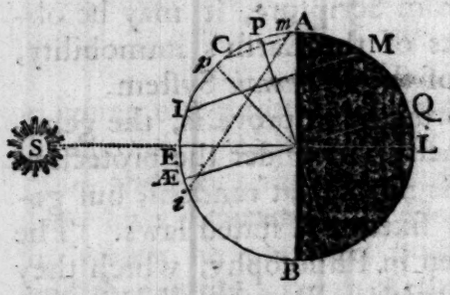
For whether we ſuppoſe, with *Ptolemy*, that the *Sun ſtood ſtill*, or, with the *Copernicans*, that the *rotation of the Earth* about her own axis was *ſtopped*, it is plain, at that time, the Sun muſt have been *vertical* to *ſome* place or *other*. But the conſequence of ſo much additional *heat* to one place, and ſuch an increaſe of *cold* to the oppoſite place, muſt have cauſed very dangerous effects.

If we embrace the *Copernican* hypotheſis, then the conſequence of the ſtoppage of the Earth's diurnal motion muſt have been beſides, that every thing would have been *thrown off* in the *Tangent* line to the place where it then was.

It may be ſaid, indeed, that Providence could have interpoſed, and prevented this. But this would be to multiply miracles, and ſeemingly without any ſufficient reaſon. For the finiſhing a battle in *one* day, which, for ought appears, might as well have been finiſhed the next, will hardly appear to have been ſuch a ſufficient reaſon.

On account of theſe difficulties, ſome perſons have been inclined to think the whole nothing more than a flight of *Eaſtern Poetry*. But in the 14th verſe of this chapter, and *Habakkuk* iii. 11. it ſeems to be referred to as a real matter of fact.

And then, ſuppoſing it to be ſo, the eaſieſt manner of accounting for it, perhaps, may be this.



From the Hiſtory it ſeems as if this battle was fought about the Summer Solſtice. Therefore let ÆQ be the Equator, and P the Pole, EL the Ecliptic, S the Sun, AB the Circle bounding light and darkneſs on the day of the *Solſtice*, when the whole Arctic Circle AC will be in the light.

Let PÆBL be a Meridian, or great Circle of the Earth, paſſing through I, the Vertex of *Jeruſalem*, and let IM be the Parallel deſcribed by *Jeruſalem*, by the *diurnal* motion of the Earth about its own axis, projected into a right line; the Arch EÆ will be the meaſure of the Angle made by the Ecliptic with the Equator, and conſequently the Sun's *greateſt declination* on the day of the Summer Solſtice, and E I the *Zenith diſtance* of the Sun the ſame day from the Vertex of *Jeruſalem*.

If then we ſuppoſe, for that time, there was an alteration made in the inclination of the Earth's axis to the plane of the Ecliptic, and the Pole P was made to dip about 35° towards the Sun, into the ſituation *p*, we ſhall find that the parallel of *Jeruſalem* I M, now *i m*, will

will not come *within*, but juſt *touch* the Circle bounding light and darkneſs, and, therefore, that the Sun would *not ſet there* that day at all.

There is no reaſon to be aſſigned in nature why the axis of the Earth ſhould be inclined to the plane of the Ecliptic in an Angle of 66 degrees and a half rather than any other quantity. There is no difficulty, therefore, in the ſuppoſition of a temporary change made in that Angle. We may now ſee this by

THE GLOBE.

Elevate the Pole 23 degrees and a half; then will the wooden Horizon repreſent the Circle bounding light and darkneſs on the day of the Summer Solſtice. Bring up *Jeruſalem* to the braſs Meridian, and ſet the hour-index to twelve at noon. Turn the Globe about its axis, and bring *Jeruſalem* to the edge of the weſtern Horizon; then will it be Sun-riſe there, and the hour-index will point to ſeven hours and a quarter; that is, the Sun will riſe ſeven hours and a quarter from noon, or at three quarters paſt four. Raiſe the Pole 35 degrees, or till 58° 30′ on the braſs Meridian touch the wooden Horizon; then will the parallel of *Jeruſalem* only touch the Circle bounding light and darkneſs, and conſequently the Sun will then not ſet there.

And this, perhaps, by the way, is at the bottom of, and gave riſe to, the ſtory of *Phaëthon*; the *Greeks* embelliſhing all the hiſtories that they learned from the *Phœnicians*, or other barbarous nations, as they called them.

We may come now to the uſe of

A SELENOGRAPHY.

Having mentioned the *Selenography* of *Grimaldi* and *Hevelius*, it may ſeem as if Aſtronomers had beſtowed a deal of uſeleſs pains in marking ſo accurately the *ſpots* on the Moon's ſurface with names. To obviate this objection, it may be remarked, that they are of great ſervice in obſerving *Eclipſes of the Moon*, as well as her *Occultations* of the *fixed Stars*, and deſcribing them to others. This will appear from an Example of each.

AN ECLIPSE OF THE MOON, MARCH 16, 1718,

Obſerved by Father KEGLER, a *Jeſuit*, at PEKIN in CHINA *.

The beginning near *Cevallerius*	$9^h\ 47'\ 07''$
The ſhadow at *Gaſſendus*	$9^h\ 58'\ 30''$
at *Eratoſthenes*	$10^h\ 10'\ 30''$
at *Tycho*	$10^h\ 12'\ 45''$
Total Immerſion	$10^h\ 43'\ 25''$
Emerſion of *Grimaldus*	$0^h\ 26'\ 30''$
of *Ariſtarchus*	$0^h\ 30'\ 20''$
of *Copernicus*	$0^h\ 41'\ 10''$
all *Tycho*	$0^h\ 49'\ 00''$
all the *Mare Criſium*	$1^h\ 15'\ 00''$
Petavius	$1^h\ 16'\ 10''$
End of the Eclipſe	$1^h\ 19'\ 40''$

AN OCCULTATION OF THE PLEIADES BY THE MOON, OCTOBER 31, 1727,

Obſerved at PEKIN in CHINA by the *Jeſuits* KEGLER and PEREIRA †.

The Immerſion of *Electra*, near and oppoſite to *Cardan*	$9^h\ 22'\ 22''$
The Immerſion of *Celæno*, oppoſite to *Harpalus*, and the middle of the *Sinus Iridum*	$9^h\ 22'\ 35''$
The Immerſion of *Maia* at *Xenophanes*, in a right line with *Ariſtarchus* and *Kepler*	$9^h\ 50'\ 25''$
The Immerſion of *Merope*, in a right line with *Tycho*, through the eaſtern margin of *Schillerus*	$9^h\ 56'\ 50''$
The Emerſion of *Celæno*, in a right line with *Pliny*, and the northern ſhoar of the *Mare Criſium*	$10^h\ 05'\ 05''$
The Emerſion of *Electra*, oppoſite to *Langrenus*, but a ſmall matter to the North	$10^h\ 09'\ 15''$
The Emerſion of *Merope*, in a right line drawn from *Tycho* between *Caſatus* and *Cabeus*	$10^h\ 13'\ 30''$
The Emerſion of *Alcynoe*, in a right line drawn from *Tycho* between *Schickard* and *Phocylides*	$10^h\ 32'\ 10''$
The Emerſion of *Maia*, oppoſite to the middle of the eaſtern ſhoar of the *Mare Criſium*	$10^h\ 45'\ 00''$
The Emerſion of *Alcynoe*, but dubious, by reaſon of Clouds	$11^h\ 06'\ 00''$

* Obſervat. Mathemat. &c. vol. i. p. 38. † Ib. p. 68.

From

From ſpeaking of Teleſcopes, and ſuch obſervations as have been laſt mentioned, we re naturally led to take ſome notice of another inſtrument of great uſe in *practical Aſtronomy*; and that is

THE MICROMETER.

The uſe of this inſtrument is for meaſuring the diameters of the Planets, and ſuch other ſmall diſtances as do not exceed a degree, or a degree and a half.

Of theſe inſtruments there are ſeveral ſorts, which it is not intended here to deſcribe.

The firſt perſon who is ſaid to have invented the *Micrometer* is a *Frenchman*,

Mr. AUZOUT,

about the year 1666; and there is a little treatiſe of his upon it, publiſhed in a work called *Divers Ouvrages de Mathematique & de Phyſique, par Meſſieurs de l'Academie Royale des Sciences*.

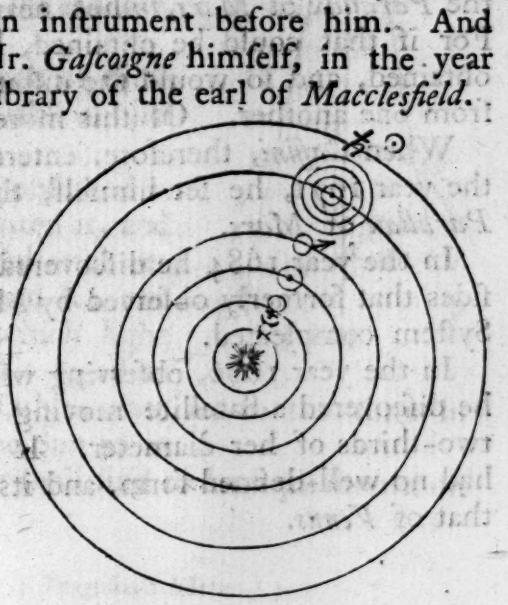
But a countryman of our own,

Mr. GASCOIGNE,

who was killed in the Civil Wars here, in the battle near *York*, in the year 1644, is ſaid to have had ſuch an inſtrument before him. And this is proved by a letter wrote by Mr. *Gaſcoigne* himſelf, in the year 1641, the original of which is in the library of the earl of *Macclesfield*.

Mr. HUYGENS

diſcovered, A. D. 1655, *Saturn*'s outermoſt Satellite, and that he was encompaſſed with a Ring, at ſome diſtance from his body. So that the Syſtem was now as repreſented here.



The Royal Society of *London* was founded by king *Charles* II. A. D. 1660.

The Royal Obſervatory at *Greenwich* was built, and

Mr. FLAMSTEED

Mr. FLAMSTEED began to obſerve there A. D. 1676, *i. e.* ſix years after the Royal Obſervatory at *Paris* was finiſhed.

His friend and patron was Sir *Jonas Moore*, maſter ſurveyor of the ordonnance, and a great encourager of mathematical learning. In Sir *Jonas*'s Syſtem of Mathematics, deſigned for the uſe of the boys educated in Chriſt's Hoſpital, *London*, Mr. *Flamſteed* inſerted his *Doctrine of the Sphere*; wherein he ſhews how, by *projections* grounded on the *Copernican* hypotheſis, all the phenomena of the Heavens may be explained and calculated, as well as by thoſe that are founded on the *Ptolemaic* hypotheſis.

But the principal thing contained in it, is his method of *conſtructing ſolar Eclipſes*, and *occultations* of the *fixed Stars*, by the *Moon*. By which means, the calculations of ſolar Eclipſes for particular places are very much ſhortened, and the *difference* of *Meridians*, or the *Longitude* of *places* determined from them.

It was obſerved before, when ſpeaking of *Hipparchus*, how difficult it is to find the diſtance of the Earth from the Sun, which, however, is the baſis of all that part of *comparative Aſtronomy*.

As it was ſcarce hoped to be obtained, by any direct obſervation, it was attempted by a kind of indirect method; and that was, by finding the *Parallax* of *Mars*, when neareſt to us, or in an achronical ſituation. For if that could be obtained, his diſtance from the Earth would be obtained, and ſo would the diſtances of all the reſt from the Sun, and from one another. Of this more will be ſeen hereafter.

When *Caſſini*, therefore, entered upon the Obſervatory at *Paris*, in the year 1671, he ſet himſelf, the next year, to enquire anew into the *Parallax* of *Mars*.

In the year 1684 he diſcovered about *Saturn* four Satellites more, beſides that formerly obſerved by Mr. *Huygens*. So that now we have the Syſtem compleated.

In the year 1686, obſerving with a Teleſcope 34 feet long, he thought he diſcovered a Satellite moving round *Venus*, at the diſtance of about two-thirds of her diameter. It had the ſame phaſis with *Venus*; but had no well-defined form, and its diameter ſcarce exceeded one-fourth of that of *Venus*.

Since

Since that time Mr. *Short* ſays *, that he ſaw the ſame Satellite, *October* the 23d, 1740, exceeding ſharp and well defined, and having the ſame phaſis with *Venus*.

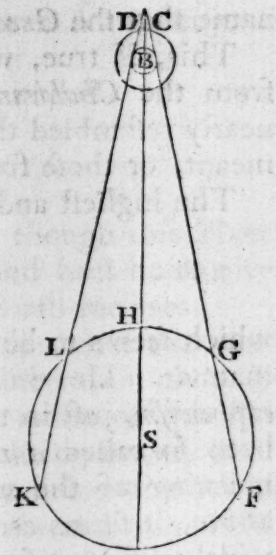
Though it was the generally received doctrine of theſe times, handed down from *Ariſtotle* and the *Peripatetics*, that light was prapagated from the moſt remote diſtances in an inſtant, yet, in the year 1675,

Mr. ROEMER

read a diſſertation, in the *Academy of Sciences* at *Paris*, to prove, from ſome obſervations on Eclipſes of *Jupiter*'s Satellites, that *light* was *propagated* from the Sun to us in about 11′ of time. Later obſervations make it 8′ 13″ of time. So that from what we know already of the Sun's diſtance from us, it will be found, that light flies at the rate of above 164000 miles in 1″ of time †.

The method whereby *Roemer* collected this ſucceſſive propagation of light, was this.

Let S be the *Sun* in the center of the *Earth*'s Orbit, whoſe ſemidiameter is SH. Let B be *Jupiter*, caſting a ſhadow to the part of the Heavens oppoſite to the Sun, and let C be one of his *Satellites*, falling into his ſhadow, obſerved at G or F; and let D be the ſame *Satellite*, emerging out of his ſhadow, ſeen from the Earth at L, or K.



Let the Chords GF, LK, be taken, each of them equal to SH, the ſemidiameter of the Earth's annual Orbit.

He found that the immerſion, when obſerved at G, fell out ſooner than the tables repreſented it, and at F later. The ſame likewiſe he obſerved with regard to the Emerſions, viewed from L and K; and the difference he aſcribed to the time which light required to deſcribe the Chords GF, LK, equal to the ſemidiameter of the Earth's annual Orbit; that is, to the time in which light would be propagated from the Sun to us.

This ſucceſſive propagation of light we ſhall find to be a phenomenon of great importance hereafter.

* Philoſ. Tranſact. No. 459. † Ferguſon's Aſtron. § 197.

As

As we have now, by the obſervations of *Huygens* and *Caſſini*, our ſolar Syſtem complete, it will not be amiſs to conſider a little in what manner the diſtances of the Planets from the Sun, and from each other, may be found. For by this means we ſhall not only be enabled to form juſter ideas of the extent of this Syſtem, but be better qualified to compute the different forces of theſe bodies upon each other, and the ſeveral effects ariſing from thence.

But before we come to this, it may not be improper to take a ſhort view of the names of the Planets, as they are delivered down to us by the ancients.

THE NAMES OF THE PLANETS.

The Planets, it is probable, had different names in different countries. Their names, in uſe among us, are borrowed from the *Greeks* and *Romans*. But even to them they were, it is evident, exotic, or derived from other people.

Diodorus Siculus ſays, that the *Chaldeans* called them by the ſame name that the *Greeks* did *.

This, if true, would induce us to think that they learned their names from the *Chaldeans*. It may be that the *Chaldean* names, in ſound, nearly reſembled the *Greek* names; and this may be all that *Diodorus* meant, or thoſe from whom he tranſcribed his account.

The higheſt and outermoſt of the Planets the *Greeks* called

Φ A I N Ω N;

which ſeems to be originally an exotic name, modelled after the *Greek* manner. He was called Φαίνων, according to *Achilles Tatius* †, by an *euphemiſm*, juſt in the ſame manner as *lucus* is ſuppoſed, by ſome, to have been ſo called *a non lucendo*; that is, the *Greeks* did not underſtand the meaning of the word. From the account given by *Diodorus Siculus* above, it ſeems as if the *Chaldeans* called this Planet by ſome name not widely different from this of the *Greeks*. To *Chaldea*, therefore, it will be proper for us to go.

But in the language of that country, the verb פנא *phana*, or פנה *phanah*, ſignifies *convertere ſe, divertere ſe, declinare*. And in the *Arabic* language too, the verb فني *phanai*, is *evanuit*, and فان *phân*, is *evanidus*. What-

* Page 116. † Page 136.

ever

ever *vaniſhes*, or *diſappears*, very properly *declines*, or *turns aſide*, from our view.

This Planet, therefore, was moſt probably called פן *Phen*, or פין *Phain*, and, with a Greek termination, ΦΑΙΝΩΝ, on account of his *withdrawing* himſelf, by reaſon of his diſtance. The *ſmallneſs* and *weakneſs* of his light, together with the *ſlowneſs* of his motion, make him likewiſe ſcarce diſtinguiſhable from the fixed Stars about him.

And this conjecture is yet farther confirmed from his name in another dialect, or among another people. For from סתר *Sater, latuit, abſcondit ſe*, with the *paragogic* נ *Nun*, which is not unuſual in the formation of eaſtern words, comes the word סתרן *Saturn*, and, with the Latin termination US, SATURNUS.

By the Arabian writers this Planet is called زحل *Zohal*, from the verb زحل *zabal*, which ſignifies *declinavit, diſceſſit, receſſit*, and which agrees, therefore, with the Chaldee פנא above.

Whether this Planet, however, was known originally to the *Arabians* by this name, doth not appear. For as they have no writings older than the time of *Mohammed*, what knowledge they had of the planetary motions, before they became acquainted with the Greek Aſtronomy, is wholly uncertain.

The Planet next inferior to this, is, by the *Greeks*, called

Ζ Ε Υ Σ.

Which word is commonly derived from ζέω, *ferveo*; though this Planet is no hotter than any of the reſt. Indeed the light and heat he receives from the Sun is almoſt 30 times leſs than what our Earth receives.

But this derivation is founded upon the ſuppoſition that the word ΖΕΥΣ is of Greek original; whereas, if *Diodorus*'s obſervation above be true, it muſt rather be Oriental. What the Chaldee name of this Planet was, is uncertain, the remains of that language being ſo very ſmall and imperfect; the oldeſt writings in that language being the Jewiſh *Targums* on the Bible, except a few chapters in *Daniel* and *Ezra*, which treat of very different ſubjects from Aſtronomy. In the Chaldee language, the verb סוח *ſevah*, or סוי *ſeve*, at preſent, ſignifies *lætari, exultare præ gaudio*. But as theſe kind of ſignifications, which expreſs only paſſions, or affections of the mind, ſeem to be but *ſecondary*, and *derivative*, we are yet at a loſs for that which is the primary and original ſenſe of the verb.

It hath been remarked, in another place, that, in the Arabic language, the word ذو *Dû*, or *Dsû*, ſignifies *Lord*, or *one that poſſeſſes*, and that

with this very properly agrees the *Dyu* of the Welſh, *Deu* in the Corniſh, *Dûe* in the Armoric, *Dia* in the old Iriſh, and the *Deus* of the Latins.

As the Grecian ΖΕΥΣ, therefore, ſeems, from their Hiſtory, however obſcured in fable, to have been a real prince, it may not be improbable that he was called by this name, as a term denoting *ſovereignty* and *dominion*.

But as to the name of the Planet, we may conceive it to have been ſomewhat different, and derived from ſome word, which, though not to be found in modern Lexicons, yet, in thoſe early times, correſponded with the Arabic word ضو *Dhû Lux, Lumen, Splendor*. A name very juſtly given to this Planet, on account of his *ſtrong* and *clear light*.

And as the Arabic verb ضاء *Dhaa*, ſignifies *luxit, micuit*, this might have been the primary meaning of the Chaldee סוה *ſevah*, as now pointed; from whence, in a derivative ſence, and transferred to the mind, it would very juſtly be uſed for *lætari, &c.*

From شرا *ſhara*, or شري *ſhari*, in the Arabic language, which ſeems, in its primitive ſenſe, to have ſignified *agitare*, and from thence, among other things, *micuit, corruſcavit*, comes مشتری *Moſhtari*, the name of this Planet, in that language, from its *brightneſs* likewiſe.

The Planet next in order to this was called, by the *Greeks*,

A P H Σ.

In the Hebrew language, the verb ארץ *aretz*, ſeems to have ſignified, primarily, *fortis fuit*, and, from thence, *violentum ſe exhibuit, violentiâ uſus eſt, terruit, &c.* And accordingly, עריץ *aritz*, is *violentus, tyrannus, formidabilis*, and agrees well enough to a perſon, or hero here, and who, after his death, was *canonized*, and reputed the *God* of *War* and *Fighting*.

According to the genius of the Chaldee languge, the ץ *Tzade* final is changed into ע *Ain*; and the verb ערע *ara* ſignifies, in *Buxtorf*'s Lexicon, *accidere, incidere, obviam fieri, occurrere, incurrere* in *general*. And from thence it might, very properly, have been uſed for *occurrere bello*, in *particular*.

That theſe were the only ſignifications of this verb, when the Chaldee was a living language, is more than ought to be maintained. The Arabic verb عرض *arada*, which correſponds to theſe two Hebrew and Chaldee verbs above, ſignifies not only *adverſus occurrit, accidit, contingit*, but likewiſe *apparuit, ob oculos patuit, conſpicuus fuit*, and, according

cording to a great maſter of Oriental learning, *vibravit*. This laſt ſignification is very applicable to the *darting*, or *ſhooting*, of rays of light, whether from a *Lance*, *Spear*, *Sword*, or *Star*.

This Planet, therefore, I ſuppoſe, was called ערץ *Ara*, ארץ *Aretz*, ΑΡΗΣ, and, in another dialect, מערע *Ma'aretz*, or MARS, in a ſofter pronunciation, from his *ſtrong glowing brightneſs*.

The next Planet to this in order, though by the ancients not eſteemed a *Planet*, is

THE EARTH,

by the *Greeks* called ΓΗ, and by their Poets ΓΑΙΑ, or ΑΙΑ.

In the Hebrew language, the word גיא *Ge*, or *Gaia*, in the preſent Lexicons, ſignifies only *Vallis*, and אי *Ai*, *Inſula*; but, perhaps, at firſt, or in the Punic or Phœnician language, from whence the *Greeks* might borrow it, the appellation might be uſed in a more extenſive manner.

The word ארץ *Eretz*, in the Hebrew language, ſeems, in many places, to be taken as equivalent to our word *Country*, and ſometimes to be uſed peculiarly of the *Land of Canaan*.

The word תבל *Thebel* is ſuppoſed to comprehend the whole habitable World, which, therefore, might be conſidered as a *round flat ſurface*. For in the Arabic language, the word طبل *Tablon*, is not only *Tympanum*, ſive *una conſtans facie*, ſive *gemina*, but likewiſe *Homines*, *populi*, *i. e.* as one might ſay, perhaps, "Thoſe that inhabit on the *diſk* of the *Earth*."

What time the *Earth* began to be conſidered, or rather ſuſpected, to be *ſpherical*, is uncertain, but hardly before the undertaking long voyages; the firſt of which, it may be, were down the *Arabian Gulph*, and out of the Streights of باب المندوب *Bâb Al-mandub*, by *Europeans* corruptly called *Babelmandel*.

What opinion was commonly entertained of thoſe that undertook thoſe long voyages, may be learned, in ſome meaſure, from this very word. For مندوب *Mandub*, is *one that is lamented at his funeral*; therefore باب المندوب *Bâb Al-mandub*, is the *Gate*, or *Straight*, *of one lamented at his funeral*; as if a perſon that ſailed beyond that, was looked upon as going to certain death, or never to return.

In the Arabic language, the word ارض *Ardh*, or *Ardhon*, which anſwers to the Hebrew ארץ *Eretz*, ſignifies *Tellus*, *Terra*, *Solum*, *Regio*, and, metaphorically, *quicquid*, *humile*, *inferum & depreſſum*.

From this word ſeems to be derived our *Earth*, the Anglo-Saxon *Eard* and *Eord*, the Daniſh *Jord*, *Jorden*, the Dutch *Erd* and *Aerd*, and the Teutonic *Erd*, *Erde*. *Hæc ſi* Græcus *eſſem* (ſays *Skinner*) *deflecterem à*

Græco Ερα *Terra, unde adverbium* Ενερθε, Νέρθε, *infra, inferius.* From all which one may form no unreaſonable conjecture, that this Planet, on which we live, had its name ארץ *Ertz*, ارض *Ardh*, *Earth*, from its ſituation with reſpect to the Heavens, which always ſeem *high*, and *over* our *heads*, and are ſo called from the verb سماء *ſamâ*, which ſignifies *altus fuit.*

The Planet next below the Earth, with reſpect to the Sun, is, by the *Greeks*, called

ΑΦΡΟΔΙΤΗ.

The name of a Goddeſs; and therefore that Planet,

Quem Venus *ante alios aſtrorum diligit ignes* *.

If what *Diodorus* affirmed, at the beginning of theſe remarks, be true, this Planet, it may be, had its name among the *Chaldeans*, like thoſe before mentioned, expreſſing its *brightneſs.* For in the Chaldee language, the verb פרד *pharad*, ſignifies *ſeparavit, disjunxit*; and in the Arabic language, from the ſame primary notion, in a ſecondary ſenſe, *ſolus, unicus, incomparabilis fuit.* Hence, in the laſt of theſe two languages, we have فريد *pharîd*, and فريدة *pharidah, gemma pretioſa, unio*; and, in the former, פרידתא *pheridta*, which ſignifies *ſeparata* in *general*, whether on account of *beauty, luſtre*, or any thing elſe.

By פרידתא *pheridta*, then, אפרידתא, *Aphridta*, and, ſoftened a little, after the Greek manner of pronunciation, ΑΦΡΟΔΙΤΗ, is meant nothing more than *eximia, formoſa, præclara.* A name very properly given to this Planet, on account of its *remarkable luſtre*; a luſtre ſo great, that it is many times ſeen in the day-time, notwithſtanding the light of the Sun.

This was once ſo remarkable, that it gave occaſion to Dr. *Halley* to enquire into the cauſe; which he did in a paper, publiſhed in the *Philoſophical Tranſactions* †, where he propoſes this Problem, "In which "part of her Orbit, with reſpect to the Earth, is the illuminated "portion of *Venus*'s diſk, turned towards the Earth, the *greateſt* that it "can be?"

And this he found to be when that Planet is about 40° diſtant from the Sun, and when little more than one-fourth of her viſible diſk is luminous, and ſhe reſembles the Moon about five days old.

* Æneid viii. ver. 590. † No. 349.

In

In every eight years time, he farther obſerves, ſhe returns to the like poſition again; ſo that ſhe may be ſeen, the ſame day of the month, and hour, nearly in the ſame place.

From the Chaldee חן *Han*, or *Hen*, which ſignifies *gratia*, *decor*, *elegantia*, with the Æolic digamma F, comes *Fen*, or *Ven*, and with the additional termination *us*, *Venus*; the name by which this Planet was known among the *Romans*, and by which, from them, it hath been tranſmitted to us.

As to the name ΔΕΛΕΦΑΤ, by which, according to *Heſychius*, this Planet was called; though it is derived, by the learned *Selden*, from דלפא *gutta*, yet, as I have ſhewn elſewhere, this is a miſtake, and ſuppoſes that the word owes its origin to the fable, that *Venus*, a perſon, was born of the *froth* of the Sea.

Whereas the word is Chaldee, and nothing more than די לפד *Di Lephad*, or, changing, at leaſt in the pronunciation, the ד into ת, *Di Lephat*, i. e. *Tædas*, vel *faces* habens; a name given this Planet, on account of its *remarkable brightneſs*, as was obſerved but juſt now.

The ſame may be ſaid of her other name, ΣΑΛΑΜΒΩ. For in another dialect, changing די into דא *Da*, or דא *Dſa*, and inſerting מ into לפד we have למפד *Lampad*, and thence דא למפדא *Dſa Lampda*, and, ſoftened a little by the *Greeks*, in their manner of pronunciation, ΖΑΛΑΜΠΩ, ΣΑΛΑΜΒΩ.

The loweſt Planet of all, and neareſt to the Sun, was called, by the *Greeks*,

Σ T I Λ B Ω N.

A name, like the reſt, plainly alluding to its brightneſs. Στίλβει (ſays *Heſychius*) λάμπει, & Στιλβῶσαι, ἀπαςράψαι.

The word ςιλβων, then, is Greek, and ſeems to be a tranſlation of the Chaldee name, whatever that was.

In the Hebrew language, the word אש *Eſh*, and, in the Chaldee, אשתא ſignifies *fire*, and, in both the Hebrew and Chaldee, להב *Lahab*, is *flame*; ſo that אשתא להב *Eſhta Lahab*, will be the ſame thing as a *flaming fire*. This, in common language, might be pronounced *Eſtlib*, and from thence the *Greeks*, in their manner, would eaſily form their ΣΤΙΛΒΩΝ. A name very properly given to this Planet, on account of its *fiery colour*.

The word אור *Oor*, in the Hebrew and Arabic languages, ſignifies *light*, *fire*, &c. And ברק *Barak*, in Arabic, as well as Hebrew, is to *lighten*.

ברק אור

ברק אור *Bark-oor*, ברק אורי *Bark-oori*, or, changing the letter ב into מ, as letters of the ſame organ frequently are ¶, מרק אורי *Mark-oori*, we have, in another dialect, with a Latin termination *us*, another name of this Planet, *Mercurius*; and from whence comes *Mercury*, as he is called by us.

We now come to the two great luminaries, the

SUN AND THE MOON;

whoſe motions being *apparently* more regular than thoſe of the other Planets, and more *obvious*, were, from thence, and the daily benefits received from them, perhaps, the firſt taken notice of, and their motions ſtudied.

The firſt of theſe is, by the *Greeks*, called

H Λ I O Σ.

Which is nothing more than the Hebrew word אל *El*, modelled after the Greek manner of pronunciation, and ſignifies *Lord*; the firſt idolatrous worſhip being paid to this Planet.

In the Hebrew language it is called שמש *Shemeſh*, and in the Chaldee שמשא *Shimſha*, from שמש *ſhameſh*, to *miniſter*, on account of its *adminiſtering light* and *heat* to this World below.

From this property of communicating *heat*, it is alſo called חמה *Hammah* *.

By the Phœnician idolaters it ſeems to have been called בעל *Baal*, or בעל שמים *Baal-ſhamim*, the *Lord of Heaven*. And on account of the ſuppoſed ſwiftneſs of its diurnal motion from *Eaſt* to *Weſt*, it had a *chariot* dedicated to it at *Sidon*, an ancient town of *Phœnicia*. Such a *chariot* is ſtill ſeen on the coins of that place †. This ſuperſtition was likewiſe imitated by the idolatrous *Jews*: for we read ‡ of *the horſes which the kings of* Judah *had given*, or dedicated, *to the Sun*.

By the *Chaldeans* it ſeems to have been called בל *Bel*, and by the *Aſſyrians* פל *Pul*, and, with the addition, ſometimes, of אב *ab*, or אף *ap*, *i. e. father*, אף-פל *Ap-Pul*, or *Father-Lord*; from whence the *Greeks* formed their

¶ Thus *Mecca* is uſed for *Becca*, according to the *Arabs* themſelves.

* Job. xxx. 28. † Noris. Epoch. Syromaced. p. 416. ‡ 2 Kings xxiii. 11.

ΑΠΟΛΛΩΝ,

A Π O Λ Λ Ω N,

another name given by them to the Sun.

The name of this Planet, among the *Romans*, was

S O L.

Quia ita eminet, ut propterea quod talis SOLUS *appareat, Sol vocetur*, ſays *Macrobius* *. In the Arabic language, the verb صال *sâl*, ſignifies *ſæviit, furit, impetum fecit*, and likewiſe *definivit modo ſuo & quantitate*. It is more probable, therefore, that the name SOL was given to this Planet on account of his *ſcorching heat* in the Summer, or from his *determining* the *length* of the *year* by his courſe, than becauſe he appeared *ſolus*, (*alone*) according the derivation given above by *Macrobius*.

The laſt Planet to be taken notice of, and neareſt to the Earth, is

THE M O O N,

called by the *Greeks* MHNH; the name, perhaps, by which ſhe was called among the *Chaldeans*. For in the Hebrew language, מנה *Manah*, and in the Chaldee, מנא *Mene*, is *numerare, ſupputare*. And the firſt *computations* of time were, moſt probably, made by *revolutions* of the *Moon*; her motion being the ſwifteſt of all the heavenly bodies.

In the Hebrew language ſhe is ſtiled ירח *Yarah*, which, in this, and the Chaldee language, is likewiſe the name for a MONTH; being governed by the courſe of the *Moon*.

In the Arabic language, the verb ارّخ *Arraha*, is *adſcripto tempore notavit*; and from thence comes ارّخ *Arhaton*, or *Arha*, i. e. *tempus deſignatum, quando ſcriptum aliquid, vel factum fuit*. From hence, likewiſe, we ſeem to have formed our word ÆRA, which ſignifies the ſame thing. There is another account, indeed, of this word, given by ſome, which is this; that when the *Romans* divided the empire, about 38 years before Chriſt, *Spain* fell to the ſhare of *Auguſtus Cæſar*; that, in memory of this, the *Spaniards* dated all their memorable events AB EXORDIO REGNI AUGUSTI. But that, in proceſs of time, only the initial letters A, E, R, A, of theſe words were uſed, inſtead of the words themſelves.

It ſeems more probable, however, that the word was borrowed from the *Moors* in *Spain*, as ſeveral others were, already taken notice of.

* In Somn. Scip. lib. i. cap. 20.

In

In the Hebrew language, the verb לון *lún*, ſignifies *pernocta e, divertere*; and, in the Arabic language, لوّن *lawwanah*, is *coloravit, colore diſtinxit, matureſcere cæpit, & colorem induere* palmæ fructus, *&c.* likewiſe, *mutavit animi affectum, eoque mutabilis fuit.*

Amidſt all theſe different, and ſeemingly unconnected, ſignifications, perhaps, it will not be very difficult to diſcover, that the primary and leading one is *mutare* in general: from thence comes to *change* colour, to *colour*, to *change* the affection; from changing the colour comes to *ripen*, when applied to fruits: from *changing*, in general, comes to *change* the road in *general*, to *change* the road to ſeek a lodging in *particular*, thence to *lodge all night.*

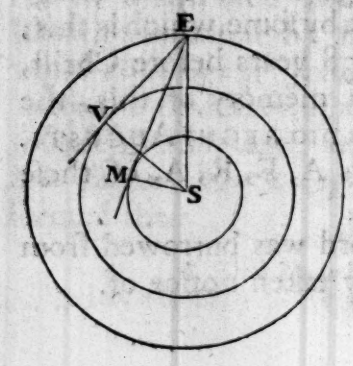
From *Lun*, then, and with the termination *a*, comes *Luna*, this name of the Planet, from her *changing*, and appearing under different *phaſes.*

It may ſeem, ſtrange, perhaps, that in theſe derivations I have mentioned the Hebrew and Arabic languages; but to obviate any difficulties on that head, it is to be obſerved, that the Hebrew, Arabic, and Chaldee, are only dialects of one and the ſame original language. Where a ſignification, therefore, is wanting in the Chaldee language, we may ſafely have recourſe to the other two, and ſee whether it may not be preſerved in one or other of them. This is nothing more than what might be ſafely practiſed, with reſpect to our own, and ſome other *northern* languages, as might be ſhewn in ſeveral inſtances, was this a proper place for it.

And now, having ſeen thus much concerning the true derivation of the names of the ſeveral Planets, we may proceed to what is of more importance; and that is, to find the

RELATIVE DISTANCES OF THE PLANETS.

And firſt, for the two inferior Planets, *Venus* and *Mercury*.



Let S be the Sun, V *Venus*, M *Mercury*, and E the Earth. Let SE, the diſtance of the Earth from the Sun, be ſuppoſed to be divided into 1000 equal parts.

Let EV be a Tangent, drawn from the Earth at E to the Orbit of *Venus* at V, and let the Angle VES (called the *Elongation* of *Venus*) be found, by obſervation, 48 degrees; then it will be, by plain Trigonometry,

Radius

Radius : Sine 48° : : ES (1000) : VS = 743

1000 - - -	3.0000000
Sine 48° - -	9.8710735
	12.8710735
Radius - -	10.0000000
VS = 743 - -	2.8710735

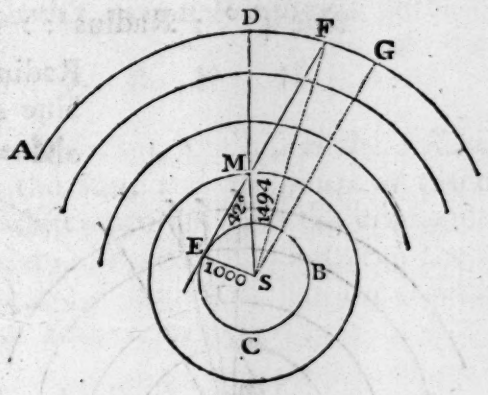
In the ſame manner, if the Elongation of *Mercury* from the Sun, or the Angle MES, be found by obſervation = 23°, then it will be,

Radius : Sine 23° : : ES (1000) : MS = 390.7

1000 - - -	3.0000000
Sine 23° - -	9.5918780
	12.5918780
Radius - - -	10.0000000
MS = 390.7 -	2.5918780

Or, becauſe Radius and 1000 are conſtant numbers, it will be the ſame thing, if to the logarithmic Sine of the *Elongation* we add the conſtant Logarithm 3.0000000. Thus,

The logarithmic Sine of 23° - - -	9.5918780
Add the conſtant Logarithm - - - -	3.0000000
MS = 390.7 Log. - - - - -	2.5918780



The relative diſtances of the ſuperior Planets, *Saturn*, *Jupiter*, and *Mars*, are found by comparing their *true* places, where they would be ſeen from the Sun, with their *apparent* places, or where they are ſeen from the Earth.

Let EBC be the Orbit of the Earth, S the Sun, M the Planet *Mars* in his own Orbit, ADFG the Orb of the fixed Stars. To an eye placed in the Sun, the Planet *Mars* (M) will be ſeen amongſt the fixed Stars at D; but by an eye placed in the Earth at E, he will be ſeen among the fixed Stars at F.

The place (D) where *Mars* is ſeen amongſt the fixed Stars, from the Sun S, is called his

HELIOCENTRIC PLACE.

But the place (F) where he appears among the fixed Stars, to an eye at E, is called his

GEOCENTRIC PLACE.

And the Arch DF, which is the difference between the true and apparent place of *Mars*, is called the

PARALLAX OF THE EARTH'S ANNUAL ORBIT,

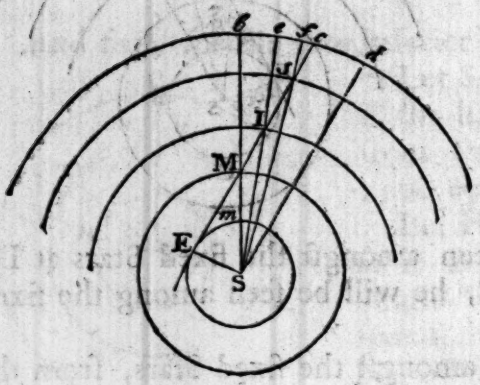
as ſeen from *Mars*, *i. e.* it is the Angle under which the ſemidiameter of the Earth's Orbit is ſeen from *Mars*.

From the Sun S draw SG parallel to EMF, meeting the Orb of fixed Stars in G; then the Angle EMS=DMF *, and the Angle DMF=DSG†, and the Angle EFS = FSG; but the Angle EFS is the Angle under which the ſemidiameter of the Earth's annual Orbit (ES) is ſeen from the fixed Stars, which, by reaſon of their immenſe diſtance, is = 0. Therefore its equal FSG = 0; therefore the point F coincides with G, and DMF becomes = DSG, and it is EMS = DMF = DSG = DSF.

In *Mars*, the Angle EMS is about 42°; therefore making, as before, ES = 1000, it will be

Sine 42° : Radius : : ES (1000) : SM = 1494

Radius + 1000	-	-	-	13.0000000
Sine 42°	-	-	-	9.8255109
SM = 1494	-	-	-	3.1744891



From whence taking ES=S*m*=1000, we ſhall have M*m* equal to the diſtance of *Mars* from the Earth, when the centers of *Mars*, the Earth, and the Sun, lie in the ſame right line, equal to 494.

What hath been here ſaid with regard to *Mars*, will equally hold good with reſpect to *Jupiter* (I) where the Parallax of the Earth's annual Orbit EIS is about eleven degrees.

* Eucl. lib. i. prop. 15. † Ib. lib. i. prop. 29.

Therefore,

Therefore, Sine 11° : Radius : : ES : SI

Radius + (ES) 1000 - -	13.0000000
Sine 11° - - - -	9.2805988
SI = 5240.9 - - - -	3.7194012

In *Saturn* at *ſ*, the Parallax of the Earth's annual Orbit, the Angle E*ſ*S is only about ſix degrees.

Therefore, Radius + 1000 - -	13.0000000
Sine 6° - - - -	9.0192346
S*ſ* = 9566.7 - - -	3.9807654

Therefore, ſuppoſing the diſtance of the Earth from the Sun to be divided into a thouſand equal parts, and their Orbits circular, the relative diſtances of all the Planets from the Sun will be, in ſuch parts, as follows,

Saturn - - - - -	9566.7
Jupiter - - - - -	5240.9
Mars - - - - -	1494
Earth - - - - -	1000
Venus - - - - -	743
Mercury - - - - -	390.7

COROLLARY I.

From what hath been ſaid, it is eaſy to ſee, that the farther the Planet is from the Sun, the ſmaller is the Earth's *annual Parallax*.

COROLLARY II.

That the further the Planet is from the Sun, the leſs is the difference betwen its true place, as ſeen from the Sun, and its *apparent* place as ſeen from the Earth. Thus, *bc*, the difference between the *true* and *apparent* place of *Mars*, is greater than *ec*, the difference between the *true* and *apparent* place of *Jupiter*; and again, *ec* is greater than the difference between the *true* and *apparent* place of *Saturn*, which is *ſc*.

COROLLARY III.

As the Angle EMS, which is the *Elongation* of the *Earth* from the *Sun*, obſerved at *Mars* (M) is about 42° ſomewhat leſs than the greateſt *Elongation* of *Venus* from the *Sun*, ſeen from the *Earth*, it follows, that

to the inhabitants of *Mars*, our *Earth* is a *Morning* or *Evening Star*, in the ſame manner that *Venus* is to us.

COROLLARY IV.

Since in *Saturn* (at *ſ*) the Angle of the Earth's *Elongation* E*ſ*S is only about ſix degrees, or nearly one-fourth of the *greateſt Elongation* of *Mercury* from the Sun, when ſeen from the Earth, it follows, that as *Mercury* is ſo ſeldom ſeen by us, being for the moſt part hid under the Sun-beams, it is poſſible that, on the like account, the inhabitants of *Saturn* may not yet have diſcovered that there is ſuch a Planet as our Earth in the Syſtem.

COROLLARY V.

That we judge partially and imperfectly of the *heats* and *colds* ſuſtained by the inhabitants of any Planet from its nearneſs to, or remoteneſs from, the Sun. Since if we imagine that every thing muſt be burned up in *Mercury*, on account of its vicinity to the Sun, with reſpect to us, the inhabitants of *Saturn* have much greater reaſon to make the ſame concluſion with regard to our Earth; whereas we know, by experience, that we feel no greater degrees of heat than what are neceſſary for *vegetation*, and the ſupport of *animal life*.

Having thus ſeen in what manner the *relative diſtances* of the Planets from the Sun may be found in ſuch parts as the ſemidiameter of the Earth's annual Orbit is ſuppoſed to be divided into one thouſand, we might now proceed to ſhew in what manner their *true diſtances* from the Sun, and from one another, may be found.

And here it may be obſerved, in the firſt place, that as the *relative diſtances* of the Planets from the Sun, before given, depend upon an *aſſumed diſtance* of the Earth from the Sun, ſo will their *real diſtances* depend upon knowing the *real diſtance* of the Earth from the Sun.

The diſtance of the Earth from the Sun, then, being the foundation of all this part of Aſtronomy, it is no wonder that ſo many learned men have taken ſo much pains to diſcover it.

The firſt perſon, that is known, at leaſt, to have attempted it, was *Hipparchus*, about the year before Chriſt 160; which he did by means of the Sun's Parallax, as hath been already obſerved.

But

But as this method depends upon knowing the true ſemidiameter of the Earth, and as that cannot be obtained, without knowing firſt the meaſure of its circumference, it will be proper to ſee what different attempts have been made to find the meaſure of.

A GREAT CIRCLE OF THE EARTH.

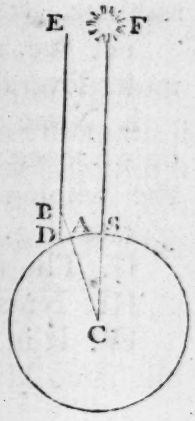
We may begin, therefore, with

ERATOSTHENES.

Whether he was the firſt perſon that made the attempt, is uncertain, but he is the firſt whoſe method is known; and it was this that follows.

But firſt we muſt premiſe from *Strabo* *, that Εν δὲ τῇ Συήνῃ, καὶ τὸ φρέαρ ἐστὶ τὸ διασημαῖνον τὰς Θερινὰς Τροπὰς, καὶ διότι τῷ Τροπικῷ Κύκλῳ ὑπόκεινται οἱ Τόποι οὗτοι, καὶ ποιοῦσιν ἀσκίους τοὺς Γνώμονας καλὰ Μεσημβρίαν· ἀπὸ γὰρ τῶν ἡμετέρων τόπων (λέγω δὴ τῶν Ελληνικῶν) προϊοῦσιν ἐπὶ τὴν Μεσημβρίαν, ἐνταῦθα πρῶτον ὁ Ηλιος καλὰ Κορυφὴν ἡμῖν γίνεται, καὶ ποιεῖ τοὺς Γνώμονας ἀσκίους καλὰ Μεσημβρίαν. Ανάγκη δὲ, καλὰ Κορυφὴν ἡμῖν γινομένου, καὶ εἰς τὰ φρέατα βάλλειν μέχρι τοῦ ὕδατος τὰς Αυγὰς, κἂν βαθύτατα ᾖ. Καλὰ κάθετον γὰρ ἡμεῖς τε ἑστάμεν, καὶ τὰ Ορύγματα τῶν Φρεάτων καλεσκεύασται. "That at *Syene* is a well which "ſhews the time of the Summer Tropic, and that theſe places lie under "the tropical Circle where the Gnomons of their Dials caſt no ſhadow "at noon. For to thoſe that travel from hence (I mean from *Greece*) "towards the South, there it is that the Sun firſt becomes vertical, and "cauſes the Gnomons to throw no ſhadow at noon. It muſt likewiſe "follow unavoidably, from the Sun's being vertical to us there, that "his beams muſt reach the water in the well, though ever ſo deep: "for we ſtand perpendicular (*to the Horizon, wherever we are*) and ſo "likewiſe are all wells dug whatſoever."

Let A be *Alexandria*, and S *Syene* in *Upper Egypt*, where the Sun F caſts no ſhadow on the day of the Summer Solſtice. Let C be the center of the Earth, and BA a Gnomon, perpendicular to the Horizon at *Alexandria*. Let BD be a ray of light falling upon the top of it, and making with it the Angle DBA. But becauſe of the immenſe diſtance of the Sun, all rays of light, coming from him, may be looked upon as parallel, therefore ED will be parallel to FS, and the Angle DBA equal to the Angle ACS †.



* P. 1172. Edit. Amſtel. 1707. † Eucl. lib. i. prop. 29.

The

The Angle DBA he found to be the one-fiftieth part of a Circle, $= \frac{360}{50} = 7\frac{1}{5}$ degrees; and the diſtance from A to S he knew was, by common computation, five thouſand ſtadia.

Therefore, $7^\circ \frac{1}{5} : 5000 :: 360^\circ : 250{,}000$ ſtadia, the whole circumference of the Earth.

This Propoſition, as before obſerved, may be looked upon as the foundation of all Aſtronomy, that concerns the diſtances of the Planets from the Sun, and from each other.

For by knowing the proportion between the circumference of a Circle and its diameter in *general*, and now having the meaſure of a great Circle of the Earth in *particular*, we ſhall have its diameter and ſemidiameter. What that ſemidiameter is, will be ſeen, more accurately, hereafter.

In the mean time, let us ſuppoſe, at preſent, in general, that the circumference of a Circle is to its diameter as 22 is to 7 (as we ſaw, when ſpeaking of *Archimedes*) or, a little more accurately, as 223 to 71, and we ſhall find, from *Eratoſthenes*'s meaſure, two different diameters of the Earth, thus;

For, 22 : 7 :: 250,000 : 79545 ſtadia.
And, 223 : 71 :: 250,000 : 75112 ſtadia.

The reaſon why theſe two proportions are here given, is only to ſhew, by theſe ſmall numbers, of what importance it is to have the proportion of the circumference of a Circle to its diameter as accurate as poſſible.

This attempt of *Eratoſthenes* ſhews great ingenuity, and the enterpriſing temper of the *Greeks*, who, as they alone raiſed Geometry to a ſcience, ſo they alone applied it to the meaſuring ſuch kind of diſtances as theſe.

Yet we may remark, by the way, that this meaſurement labours under ſeveral defects.

I. None of theſe numbers give the exact proportion between the circumference of a Circle, and its diameter; which is the foundation of the whole: the neareſt proportion, in ſmall numbers, being that of 355 to 113.

II. The true quantity of the Greek ſtadium is unknown.

III. No allowance is made for ſuch rays as come from the Sun's limb.

IV. It is not ſtrictly true that *Syene* lies under the Tropic, nor under the ſame Meridian with *Alexandria*. Nor,

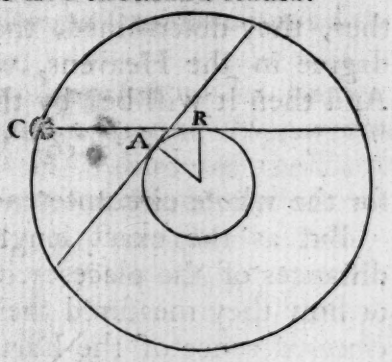
V. Doth

V. Doth it appear by what method the diſtance between *Syene* and *Alexandria* was determined. If it was only by common computation, it is eaſily underſtood how erroneous, for the moſt part, that is.

Long after the time of *Eratoſthenes*, this Problem, of finding the meaſure of a great Circle of the Earth, was attempted by *Poſidonius*, as we learn from *Cleomedes* *. This was in the time of *Cicero*, juſt before the beginning of the Chriſtian æra.

His method was this: He ſuppoſed that *Rhodes*, the capital of the Iſland of that name, lay under the ſame Meridian with *Alexandria* in *Egypt*, and that the diſtance between them was five thouſand ſtadia.

According to his obſervation, the Star called the *Canopus* (C) which was but juſt viſible at *Rhodes* (R), yet at *Alexandria* (A), when on the Meridian, was elevated above the Horizon ſeven degrees and a half.



From whence, by an eaſy proportion, it will be,

7½ deg. : 5000 ſtad. :: 360° : 240,000 ſtad.

the meaſure of the whole circumference of the Earth.

But this method fails, in point of accuracy, as well as the former.---For,

I. *Rhodes* and *Alexandria* do not lie under the ſame Meridian.

II. The diſtance between *Rhodes* and *Alexandria* was not obtained by menſuration, but, perhaps, only from the eſtimation of ſailors and navigators.

III. There is no allowance made here for Refractions, which *Poſidonius* knew nothing of; ſo that the height of the *Canopus*, above the Horizon of *Alexandria*, is made greater than it ought to be.

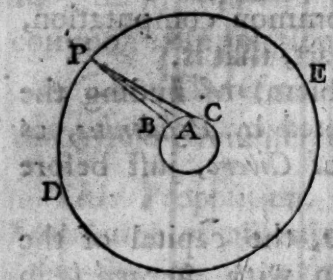
When the *Arabians*, under *Al Maimon*, the ſeventh caliph of *Babylon*, who began his reign A. D. 814, applied themſelves to mathematical Sciences, they likewiſe, by the encouragement of that prince, made a freſh attempt to meaſure a great Circle of the Earth; and this they did in the plain of *Sinjar* in *Meſopotamia*, ſuppoſed to be the ſame with the plain of *Shinar*, mentioned in *Geneſis* †.

Their method was this.

* Lib. i. cap. 26.

† Chap. x.

Let



Let DPE be a Meridian in the Heavens, and BAC a corresponding Meridian on the Earth.

Let A be the place of the obſervers, where they took the height of the Pole Star (P) as accurately as they could.

They then ſeparated; and part of them going to B, found the height of the Pole Star raiſed one degree; and the reſt going to C, found it as much depreſſed. Having then meaſured the Arches AB and AC, and comparing their meaſurements together, they determined, that an Arch of the Meridian, anſwering to one degree in the Heavens, was equal to 56 Arabian miles and two-thirds. And then it will be, by the common *Golden Rule*,

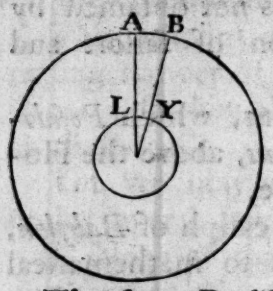
$$1^\circ : 56\tfrac{2}{3} \text{ Miles} :: 360^\circ : 20{,}400 \text{ Miles}$$

for the whole circumference of the Earth *.

But as the exact length of the Arabian mile is not known, nor the diſtances of the places where they obſerved the height of the Pole Star, or how they meaſured their diſtances, we are yet at a loſs for the true circumference of the Earth.

Upon theſe accounts, and conſidering the importance of the Problem, the reſolution of it hath been attempted ſeveral times ſince the revival of learning in *Europe*; as, particularly,

I. By *Snellius*, a *Dutch Mathematician*, A. D. 1617.



II. By our countryman *Norwood*, A. D. 1635, who, meaſuring the diſtance between *London* and *York* (LY), found it to be 905,751 *London* feet; and then taking the difference of Latitude between the two places (AB), he found it to be = 2° 28′. From whence he collected, that the Arch of a Meridian, anſwering to 1° in the Heavens, is equal to 367,196 *London* feet.

The ſame Problem was afterwards undertaken in *France*.

III. By *Picart*, in *October* A. D. 1670.

IV. By *Caſſini*.

And in the year 1735, Mr. *Godin*, *Condamine*, and *Bouger*, went to *Peru*, in order to meaſure a degree of a great Circle under the Equator; as M. *Maupertuis*, *Clairaut*, *Caimus*, and *Le Monnier*, went the next

* See Gol. Not. on Alfragan. p. 72.

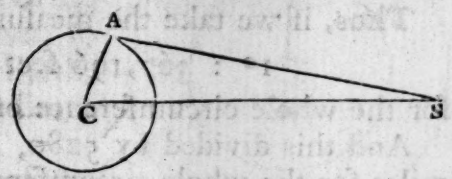
year,

year, *i. e.* 1736, to measure a degree of a great Circle under the Polar Circle.

The reason why these went to such different and far distant places, is, because though the Earth was formerly supposed to be perfectly spherical, and, in common cases, may still be looked upon as being so, yet it hath been found, by later and more accurate observations, that the Earth is flatter towards the Poles than under the Equator; so that a degree in the Heavens doth not correspond with equal Arches of the Meridian towards both those places. Arches on the Meridian, therefore, being taken towards the Poles, and towards the Equator, the Medium may be assumed; and consequently the *mean* circumference, and *mean* semidiameter of the Earth, will be given.

The circumference of the Earth being now supposed to be known, and the Sun's horizontal Parallax found, by the method of *Hipparchus*, or any other, we may now see in what manner the distance of the Earth from the Sun may be determined in semidiameters of the Earth.

Let S be the center of the Sun, C the center of the Earth, AC the semidiameter of the Earth, seen from the center of the Sun, under the Angle ASC, called the Sun's *horizontal Parallax*. Then it will be, supposing AC equal to (1) Unity, Sine of ASC : Radius :: 1 : SC, the distance of the Earth from the Sun; which, therefore, will be given in semidiameters of the Earth.



Then, if the semidiameter of the Earth can be obtained, in known measure, the distance of the Sun from the Earth will be so too. For it will be as 1 to SC, so will that known semidiameter be to the distance required.

The immense distance of the Sun from the Earth, and the extreme smallness of the Angle ASC, not to be found accurately enough for the purpose by *Hipparchus*'s method, make it impossible to be of any service.

As the Moon is much nearer to the Earth than the Sun, her horizontal Parallax must be much greater than the Sun's; but the horizontal Parallax of the Moon may, without much difficulty, be obtained. Therefore, having the circumference of the Earth, and from thence its semidiameter, we may, by the same method as with regard to the Sun, find the distance of the Moon from the Earth.

But having the distance of the Moon from the Earth, we saw before, when speaking of *Aristarchus Samius*, how, by his method, the distance of

the Sun from the Earth might be obtained. But we ſaw likewiſe, at the ſame time, upon what accounts his method is defective.

Since, therefore, we find there is no direct method of obtaining the Sun's diſtance from the Earth, either by his own or the Moon's horizontal Parallax, the ſame hath been attempted, ſince the revival of letters in *Europe*, by an indirect method; and that is, by finding the

HORIZONTAL PARALLAX of MARS.

For as the mean diſtance of *Mars* from the Earth, in his acronychal ſituation, is nearly five times leſs than the Sun's, his horizontal Parallax will be nearly five times greater than the Sun's.

We muſt, therefore, only now ſuppoſe, that if an Arch of a great Circle of the Earth, correſponding to one degree in the Heavens, can be obtained, by any of the preceding methods, the meaſure of the whole circumference of the Earth will be obtained by the common *Golden Rule*.

Thus, if we take the meaſure of our countryman *Norwood*, it will be,

1° : 367,196 feet : : 360° : 132,190,560 feet,

for the whole circumference of the Earth in feet.

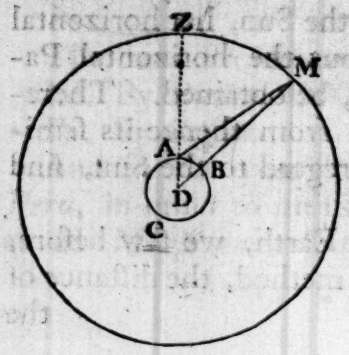
And this divided by 5280, the feet in a mile, will give nearly 25036 miles for the whole circumference of the Earth.

The whole circumference of the Earth being now given in known meaſure, we may eaſily find the ſemidiameter of the Earth in known meaſure. For ſince the circumference of a Circle is to its diameter as 355 to 113, it will be

355 : :113 : : 25036 : 7969 miles,

the diameter of the Earth; the half of which will be the ſemidiameter of it = 3984½.

This being laid down, we may now proceed to find the true diſtances of the Planets, thus.



Let ABC be a great Circle of the Earth, D its Center, M the place of *Mars* in his own Orbit, A the place of an obſerver on the Earth's ſurface, B the place on the Earth's ſurface to which *Mars* is at that time vertical, which will be known from the theory of *Mars*'s motion, and conſequently the Arch of a great Circle on the Earth's ſurface AB, the meaſure of the Angle ADB, which, therefore, will be known.

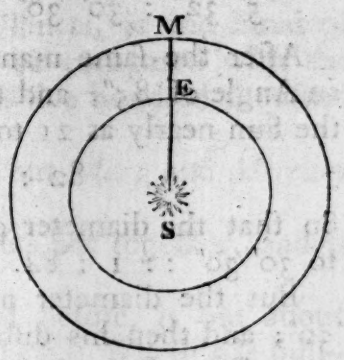
Let

Let Z be the Vertex of the place A, and the Angle ZAM the obſerved diſtance of *Mars* from the Vertex, which, therefore, will be known, and conſequently the Angle MAD, its complement to two right Angles, will be known.

But the Angle ZAM is the external Angle of the Triangle AMD, and therefore equal to the two internal ones AMD and ADM *. But the Angle ADM was ſuppoſed to be known before; and therefore ſubtracting this out of the Angle ZAM, there remains the Angle AMD, which therefore will be known.

Say then, As the Sine of the Angle AMD is to the Sine of the Angle MAD, ſo is AD, the ſemidiameter of the Earth, = 3984 miles, to DM †, the diſtance of *Mars* from the center of the Earth, which therefore will be known.

Then ſuppoſing S to be the Sun, E the Earth, and M to be *Mars*, whoſe centers all of them lie in the ſame right line, it will be, as the *relative* diſtance of *Mars* from the Earth, is to the *relative* diſtance of the Earth from the Sun, ſo will be the *true* diſtance of *Mars* from the Earth, juſt now found, to the *true* diſtance of the Earth from the Sun.



And it will be, as the *relative* diſtance of the Earth from the Sun, to the *relative* diſtance of any Planet from the Sun, ſo will be the *true* diſtance of the Earth from the Sun, to the *true* diſtance of the ſame Planet from the Sun.

And in this manner may be found

THE TRUE DISTANCES OF ALL THE PLANETS,

both from the Sun, and from one another.

Having thus ſeen in what manner the true diſtances of the Planets from the Sun may be found, we may proceed, in the next place, and enquire in what manner the proportions of their bulk to each other may be found.

It hath been obſerved already, that Mr. *Auzout*, a *Frenchman*, laid claim to the invention of the *Micrometer*, an inſtrument fitted to Teleſcopes, in order to meaſure ſuch ſmall Angles as are ſubtended by the

* Eucl. lib. i. prop. 32. † Prop. iv. p. 6.

diameters of the Planets. It is by means of these Angles that we can find the proportion they bear to the Sun, and to each other.

Thus *Jupiter*'s diameter, when he is nearest to us, is found to be 64″. But his distance, then, is to the Sun's mean distance from us as 26 is to 5.

Since then the apparent diameters of objects are, inversly, as their distances, say

$$5 : 26 :: 64'' : \frac{64 \times 26}{5} = 5' 32''$$

That is, this would be the apparent diameter of *Jupiter*, was he viewed at the same distance from us that the Sun is at.

But the Sun is seen under an Angle of 30′ 30″; therefore the proportion of *Jupiter*'s diameter to that of the Sun is as

$$5' 32'' : 30' 30'' :: 332'' : 1830'' :: 1 : \frac{1830}{332} :: 5\tfrac{1}{2} \text{ nearly.}$$

After the same manner, *Venus*, when nearest to the Earth, subtends an Angle of 85″; and then her nearest distance is to the mean distance of the Sun nearly as 21 to 82. Therefore say

$$82 : 21 :: 85'' :: \frac{85 \times 21}{82} = 21'' 45'''$$

So that the diameter of *Venus* is to the diameter of the Sun as 21″ 45‴ to 30′ 30″ :: 1 : 84.

But the diameter of *Mars*, when nearest to us, is not greater than 30″; and then his distance is to the mean distance of the Sun as 15 to 41. Therefore 41 : 15 :: 30″ : 11″ very nearly; and the diameter of *Mars* will be to the Sun's diameter as 11″ : 30′ 30″ :: 11″ : 1830″ :: 1 : 166. This, being almost double to 84, shews that the diameter of *Mars* is but half as big as that of *Venus*.

Hevelius found, by observation, that the diameter of *Mercury* is to the diameter of the Sun as 1 : 290.

Let us now suppose the diameter of the Sun to be divided into one thousand equal parts. Then, since the diameter of the Sun was found before to be to the diameter of *Jupiter* as $5\frac{1}{2} : 1 :: \frac{11}{2} : 1 :: 11 : 2$, it will be, 11 : 2 :: 1000 : 181.

And, in the same manner, may the proportions of the rest be determined, and will stand, as in the following table.

The diameter of the Sun is to the diameter of	*Saturn*	as 1000 is to	137
	Jupiter		181
	Mars		6
	Earth		12
	Venus		12
	Mercury		4

And

And becauſe Spheres are to each other as the cubes of their diameters,

The Sun will be to	*Saturn*	as 1000 millions to	2571353
	Jupiter		5929741
	Mars		216
	Earth		1728
	Venus		1728
	Mercury		64

Therefore, the ſum of the bulk of all the Planets, put together, will be to the Sun's bulk as 8,504,830 : 1000000000 : : 1 : 117.

That is, the Sun is 117 times bigger than all the Planets put together.

In the ſame manner, *Saturn* will be found four hundred times leſs than the Sun; *Jupiter*, the biggeſt of all the Planets, is one hundred times leſs than the Sun; but our Earth, if it be compared with the Sun, is not bigger than a phyſical point; for it is five hundred thouſand times leſs than the Sun.

Venus is of the ſame bigneſs with our Earth; but *Mars* and *Mercury* are leſs than the Earth.

Jupiter is bigger than all the reſt of the Planets put together, and is above two thouſand times bigger than the Earth.

The Sun's horizontal Parallax, as was obſerved before, is but about 8″; and therefore theſe numbers will want correction. But this is ſufficient for ſhewing the method.

And this brings us to

Dr. HALLEY.

Whether the Angle made by the Ecliptic, and the Equator, has been always the ſame, we have ſeen already hath been doubted by ſome Philoſophers. He therefore recommends, *to thoſe that are curious of ſuch matters*, to make ſome good obſervations on the height of the Pole at *Aracta*, or *Arecca*, a town on the *Euphrates*, whoſe Latitude was obſerved by *Al Batani*, with great accurateneſs, about eight hundred years ago, in order thereby to determine the controverſy *.

He farther recommends to curious merchants, or travellers, to obſerve, with due care, the phaſes of the Moon's Eclipſes at *Bagdat*, *Aleppo*, and *Alexandria*, in order thereby to determine their Longitudes, as the

* Miſcell. Curioſ. vol. iii. p. 177.

greateſt

greateſt ſervice they can do Aſtronomy. "For in, and near, theſe places "(ſays he) were made all the obſervations, whereby the *mean motions* "of the Sun and Moon are limited. And then (continues he) I could "pronounce in *what proportion* the *Moon's motion* doth *accelerate*; which "that it doth, I think I can demonſtrate; and ſhall (God willing) one "day make it appear to the public †."

It was by comparing ſome ancient and modern obſervations together, that he was led to this diſcovery. "*Collatis quidem obſervationibus* "*Eclipſium* Babylonicis *cum iis* Albategnii, & *cum hodiernis* (ſays Sir "*Iſaac Newton* ‡) Halleius *noſter* motum medium Lunæ *cum* motu diurno "Terræ *collatum, paulatim accelerari, primus omnium, quod ſciam, depre-* "*hendit*." Which words, however, it muſt be obſerved, are, for ſome reaſon or other, dropped in the third edition of the *Principia*.

What the quantity of this acceleration was ſuppoſed by Dr. *Halley* himſelf to be, is uncertain. Mr. *Whiſton* § ſuppoſes it to be at the rate of *one minute* (1′) in 54 years.

Mr. *Dunthorne* ¶, ſuppoſing this accelaration to be uniform, makes it only at the rate of *ten ſeconds* (10″) in one hundred years.

In the year 1675, though but a young man of twenty-one years of age, he was ſent by king *Charles* II. to the iſland St. *Helena*, to obſerve thoſe Stars that lie towards the South Pole, and are inviſible in theſe northern Latitudes. He publiſhed a catalogue of 373 Stars, and adapted their places to the end of the year 1677.

He compoſed, likewiſe, a map of the Zodiac, containing the places of all ſuch Stars as lie in, or near, the Moon's way, in order that, by obſerving her appulſe to any of them, the Longitude of places might be found by land, or ſea, as will be ſeen hereafter. A point of great importance; as without it, the art of Navigation muſt remain imperfect.

In the *Philoſophical Tranſactions* ‖, Dr. *Halley* propoſed a method whereby, from the paſſage of *Venus* over the Sun in *May* 1761, the diſtance of the Earth from the Sun might be determined to greater exactneſs than had been done before. By the alteration of the ſtyle here in *England*, this tranſit will now be *June* the 6th. But as this makes no difference in the method itſelf, it will not be improper, conſidering the importance of the ſubject, to add a few words in general concerning it.

It hath been already obſerved in what manner the relative diſtances of the Planets from the Sun, and from each other, may be found. And we have ſeen in what manner, likewiſe, having the ſemidiameter of the

† Miſcell. Curioſ. p. 177. ‡ Princip. p. 481. edit. 2. § Six Diſſert. p. 158.
¶ Philoſoph. Tranſ. No. 492. ‖ No. 348.

Earth

Earth in known meaſure, and the Parallax of *Mars* in his acronychal ſituation, his true diſtance from the Earth will be given.

But the true diſtance of *Mars* from the Earth being given, with the relative diſtance of the Earth from the Sun, it hath been ſhewn in what manner the true diſtance of the Earth from the Sun may be found.

The true diſtance of the Earth from the Sun being the foundation of all comparative Aſtronomy, it is no wonder that it ſhould be ſo particularly enquired after; and if it is not yet ſufficiently aſcertained, it muſt be aſcribed to the nicety of the obſervations upon which it depends.

If the Sun's horizontal Parallax could be determined by any direct obſervation, his diſtance from the Earth would be eaſily obtained by *plain* Trigonometry. But as that cannot be done, recourſe hath hitherto been had to indirect methods, as to the Parallax of *Mars*.

From ſuch obſervations as have hitherto been made, the leaſt that the Sun's horizontal Parallax hath been ſuppoſed, is ten ſeconds, and the greateſt twelve ſeconds and a half. But as it may be ten ſeconds and a half, or eleven ſeconds, or eleven ſeconds and a half, or twelve ſeconds, or any other intermediate number, there will ariſe, according to all theſe various ſuppoſitions, different diſtances of the Sun from the Earth.

If the Sun's horizontal Parallax is ſuppoſed only ten ſeconds, the diſtance of the Sun from the Earth will be eighty-two millions five hundred and ſix thouſand Engliſh miles.

If the Sun's horizontal Parallax is ſuppoſed to be twelve ſeconds and a half, the diſtance of the Sun from the Earth will amount but to ſixty-ſix millions fifty-ſeven thouſand ſix hundred Engliſh miles.

The difference between theſe number is ſixteen millions four hundred forty-eight thouſand four hundred. So that if the Sun's horizontal Parallax is not leſs than ten ſeconds, nor greater than twelve ſeconds and a half, it is plain that the diſtance of the Earth from the Sun is known only within ſixteen millions four hundred forty-eight thouſand four hundred Engliſh miles.

The reaſon is owing to the extreme ſmallneſs of theſe Angles. For if we take

The reſult of the Parallax of 12″ - -	68,754,800	miles
And ſubtract it from the reſult of that of 10″	82,506,000	
The difference 2″ will give - - -	13,751,200	miles

Therefore, if an error of only two ſeconds is committed in the obſervation, as is very poſſible in ſuch ſmall Angles, there ariſes an error,

we

we ſee, in the Sun's diſtance from us, of thirteen millions ſeven hundred fifty-one thouſand two hundred Engliſh miles.

But Dr. *Halley* made no doubt, but that, by his method of obſerving the tranſit of *Venus* over the Sun, his horizontal Parallax might be determined within one-fortieth part of a ſecond.

For he ſuppoſed, that in places near the mouth of the river *Ganges* in the *Eaſt-Indies*, the time of this tranſit, by means of the Parallax of *Venus*, would be *contracted* eleven minutes of time; and in places near *Port Nelſon* in *North America*, it would be *protracted* ſix minutes of time. The whole difference, therefore, is ſeventeen minutes; therefore, to an obſerver at *Port Nelſon*, the tranſit of *Venus* would laſt ſeventeen minutes of time longer than to an obſerver at the mouth of the *Ganges*.

But if, at the time of obſervation, this difference in the time ſhould be found greater or leſs, then the Sun's Parallax would be greater, or leſs, nearly in the ſame proportion. Say, then,

The Sun's horizontal Parallax - - - $12''\frac{1}{2}$
: Is to the difference in time $17' = - - 1020''$
:: $1''$ of the Sun's horizontal Parallax
: Is to the time correſponding - - $81''\frac{3}{5}$ (nearly) $= 80''$

Therefore to every eighty ſeconds of time that this difference ſhall then be found, by obſervation, to be greater, or leſs, than ſeventeen minutes, there muſt be *added*, or *ſubtracted*, one ſecond of the Sun's Parallax.

If then this difference of time can be obtained within two ſeconds of time, by obſervation, it will be as

$80''$ of Time
: $1''$ of the Sun's Parallax
:: $2''$ of Time
: The Sun's Parallax correſponding $=$ - - $\frac{2}{80} = \frac{1}{40}$

Therefore, now the Sun's horizontal Parallax will be obtained, within one-fortieth Part of a ſecond.

But if the Sun's Parallax can be obtained, within one-fortieth Part of a ſecond, then, as he ſuppoſed, the diſtance of the Sun from the Earth may be determined, within the 500th part of his whole diſtance.

For ſuppoſing the whole diſtance of the Sun from the Earth (whatever it be) to be $= 1$, and the Sun's Parallax (with Dr. *Halley*) to be $= 12''\frac{1}{2} = \frac{25''}{2}$, it will be, as the Sun's Parallax, $\frac{25''}{2}$ is to

: The

: The whole distance of the Sun from the Earth = 1
:: So will be the one-fortieth part of a second of the Sun's Parallax
: $\frac{1}{40} \times \frac{2}{25} = \frac{2}{1000} = \frac{1}{500}$.

Let the distance of the Earth from the Sun be estimated, with modern Astronomers, in round numbers, at 81,000,000 miles. Then, $\frac{81000000}{500}$ = 162,000 miles, which is but little more than half the distance of the Moon from the Earth.

In what hath been said, it hath been taken for granted, that the Sun's Parallax is twelve seconds and a half, and that the *duration* of the transit, as observed at the mouth of the *Ganges*, may be compared with the *duration* of it, as observed at *Port Nelson*.

The Sun's Parallax, we have seen, is left to be corrected by observation at the time. But that cannot be by comparing the *durations* of the transit, as seen at the places above specified.

For when Dr. *Halley* composed his Dissertation on this subject, he had not formed his own tables; and the *Rudolphine* tables, which he followed, were not accurate enough to give the true time of the *conjunction* of *Venus* with the Sun.

Port Nelson lies nearly, according to modern observations, in Latitude 57° 30′ North; and *June* the 6th the Sun will rise there at 44′ 40″ past three in the morning, and will set there at 15′ 20″ past eight at night. *Port Nelson* lies in about 90 degrees, or six hours of western Longitude from *London*; therefore, by calculation,

Venus will first touch the Sun's limb at *London* at -	2h 02′ 43″
From which subtracting the difference of Meridians -	6h 00′ 00″
We have the time when *Venus* will first touch the Sun's limb the evening before - - - - -	8h 02′ 43″
Time of Sun-set at *Port Nelson* - - -	8h 15′ 20″
Difference - - - - - - -	0h 12′ 37″

At *Port Nelson*, therefore, *Venus* will first touch the Sun's eastern limb near a quarter of an hour before Sun-set; and for that reason the beginning of the transit will be visible there.

From the time of the last external contact at *London* -	8h 47′ 27″
Subtract the difference of Meridians - - - -	6h 00′ 00″
Venus leaves the Sun's disk at *Port Nelson* at - - -	2h 47′ 27″
Time of Sun-rise there - - - - - - - - -	3h 44′ 40″
Difference - - - - - - - - - - - - - -	0h 57′ 13″

Venus, therefore, leaves the Sun's diſk at *Port Nelſon* almoſt an hour before Sun-riſe. Conſequently the end of the tranſit there is inviſible.

As the *whole duration* of the tranſit, therefore, cannot be ſeen at *Port Nelſon*, it cannot be compared with the *whole duration* of the tranſit as obſerved at the mouth of the *Ganges*, or at *Bencoolen*, as Dr. *Halley* propoſed. For which reaſon no perſon need be ſent to *Port Nelſon* to make obſervations there.

As the *Rudolphine* tables erred in the time of the conjunction of the Sun and *Venus*, ſo of courſe they erred likewiſe in the Latitude of *Venus* at the time, which would make an alteration in the length, or duration, of her tranſit.

The apparent time of the conjunction at *London*, by calculation from Dr. *Halley*'s tables, appears to be at 47′ 16″ paſt five o'clock in the morning; when the Latitude of *Venus* will be 9′ 51″ South, inſtead of 4′, as in Dr. *Halley*'s Diſſertation. And if we reckon from the time of the firſt *external* contact of *Venus* with the Sun to her laſt, the *whole duration* of the tranſit will be no more than 6^h 44′ 44″, inſtead of eight hours, as ſuppoſed in Dr. *Halley*'s Diſſertation, above referred to.

This is ſaid with regard to the tranſit, as obſerved from the center of the Earth only. For as the *viſible* path of *Venus* over the Sun will be depreſſed, by means of her Parallax, even *this duration* will be ſhortened on that account.

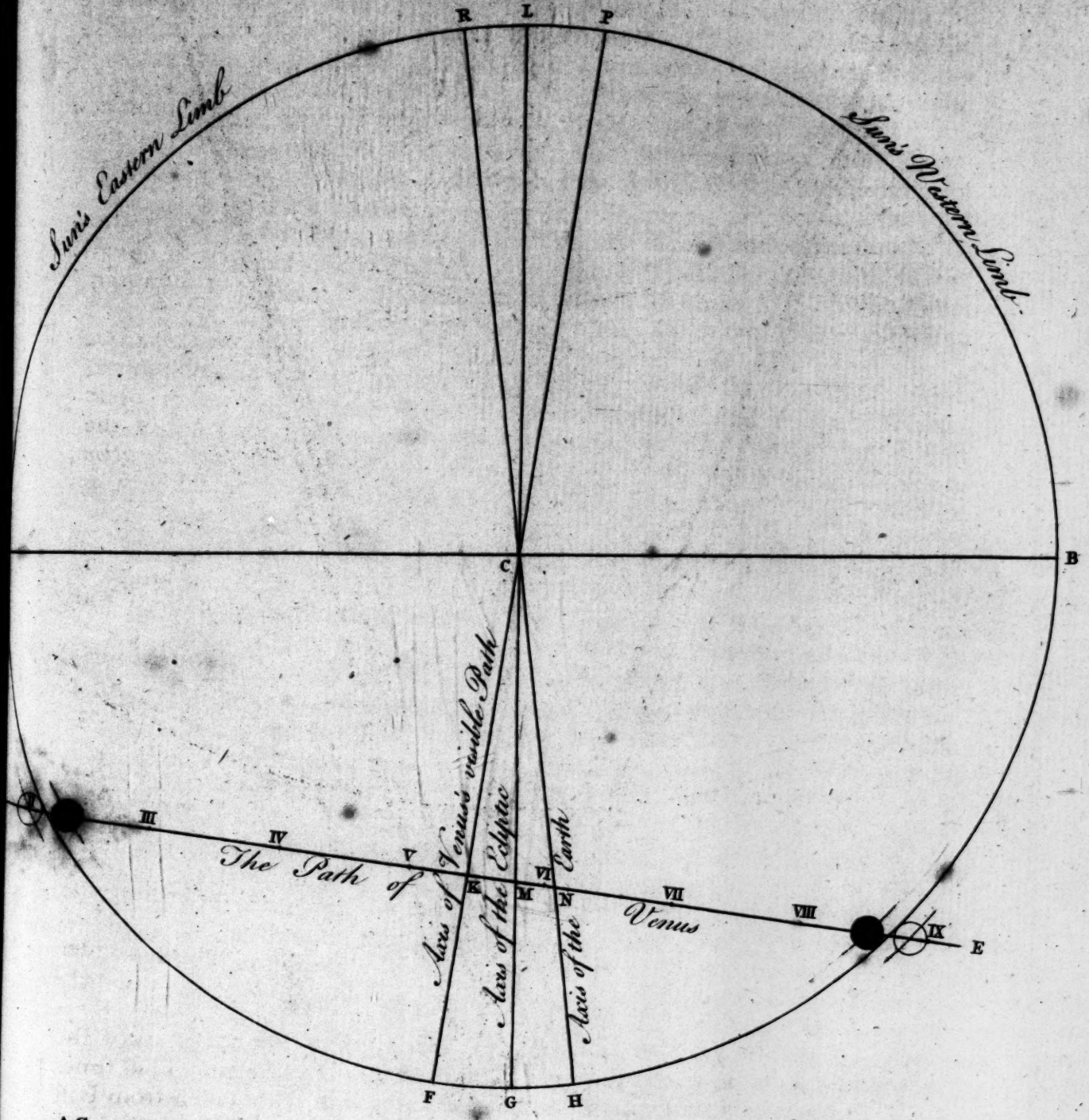
And as the Parallaxes of *Venus*, like thoſe of the Moon, are continually altering, and are different at different places, it will follow, that the duration of this tranſit at different places, will, on this account, be different.

What that difference is can only be had by *calculation*, or a *conſtruction* for thoſe particular places, after the ſame method as in the *conſtruction* of ſolar Eclipſes, now commonly known. But as this cannot be ſo conveniently explained in diſcourſes of this nature, it will be ſufficient to add here a repreſentation, or type, of this tranſit, as ſeen from the center of the Earth.

Here AC is the ſemidiameter of the Sun's diſk, ſeen from the center of the Earth, = 15′ 50″, AB a portion of the Ecliptic, GL a line perpendicular to it, or the projection of its axis on the Sun's diſk, DE is the viſible path of *Venus* over the Sun's diſk, on which are marked the times and places of the center of *Venus* during her tranſit. The times are marked as they are reckoned at *London*, and they are taken from Eaſt to Weſt; becauſe *Venus* being an inferior Planet, her viſible motion, at her

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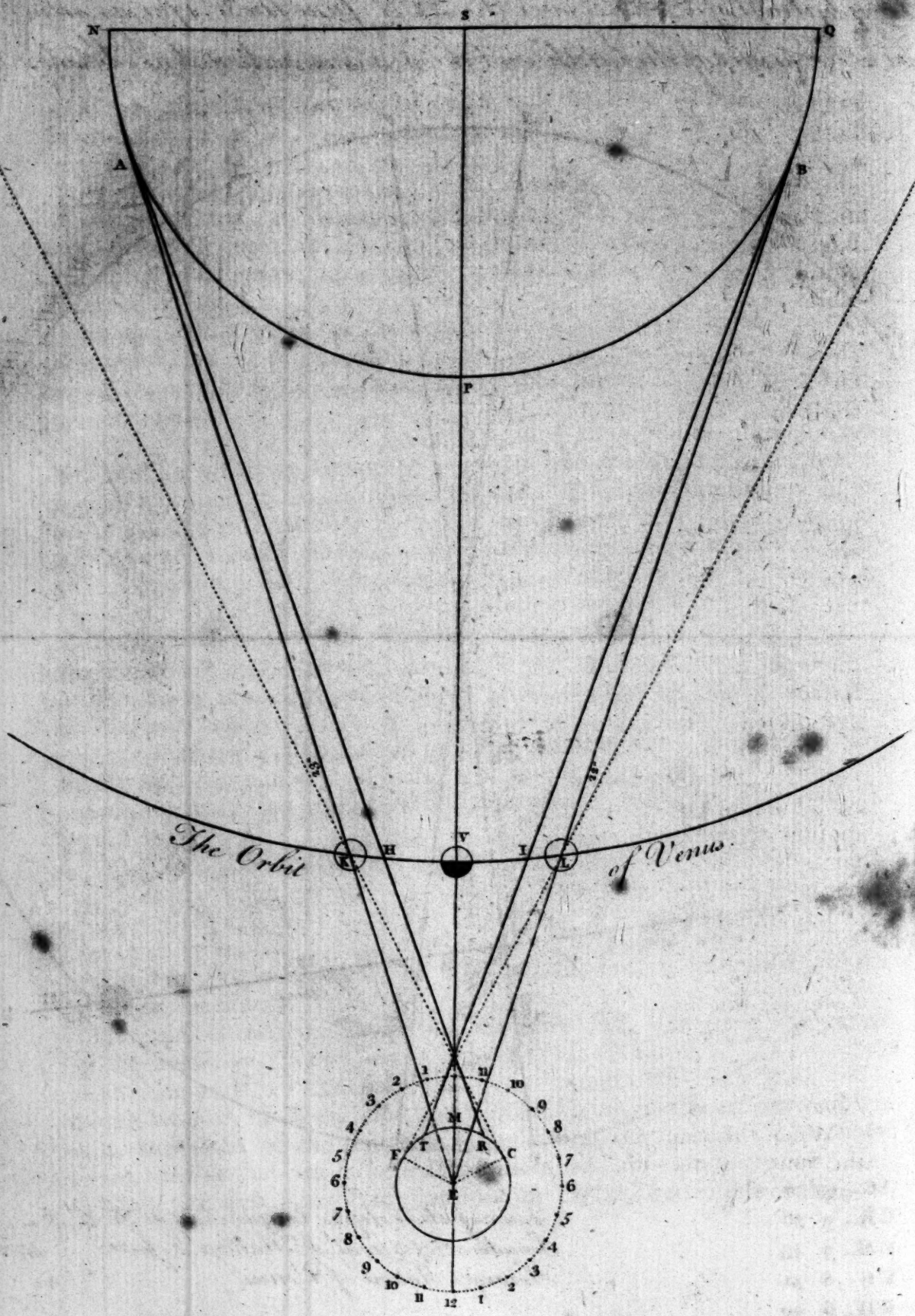
The Transit of VENUS over the SUN June the 6th. 1761, as seen from the Center of the Earth and the Times as reckoned at London.



AC =	15	50	
CK =	9	36	
CM =	9	43	
FG =	8	31	
GH =	6	00	

Time of the Ecliptic Conjunction at M	5.	46.	
Semidiam.r of ♀ from Dr. Halley's Defect.		37	½
Horary Motion of Venus		4	

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her conjunction, is *retrograde*. CM, in the axis of the Ecliptic, is the Latitude of *Venus* at the time of the conjunction 9′ 43″; and CK, in the axis of the path of *Venus*, is the neareſt approach of the center of *Venus* to the center of the Sun's diſk 9′ 36″. FG is the meaſure of the Angle made by the axis of *Venus*' path with the axis of the Ecliptic 8° 31′. RH is the projection of the Earth's axis on the diſk of the Sun, inclined to the axis of the Ecliptic in the Angle GCH, the meaſure of which is GH, ſix degrees.

Let NQ be the diameter of the Sun, E the center of the Earth, V *Venus* in conjunction with the Sun; let KHVIL be a portion of the Orbit of *Venus*. If the diſtance between the centers of the Sun and the Earth SE be divided into ten equal parts, then the diſtance between the centers of the Sun and *Venus* will be 7,2 of ſuch parts.

Theſe are called the *relative mean diſtances* of the Earth and *Venus*. But if we would have their relative diſtances at the time of the conjunction, then they muſt be found by calculation; and by that it will appear, that if the diſtance of the Sun from the Earth be divided into 1015 equal parts, then SV, the diſtance of *Venus* from the Sun, will be 726 of thoſe parts.

Let the Earth revolve about its axis from Weſt to Eaſt, according to the order of the figures 1, 2, 3, 4, *&c.* and C be a place on the Earth's ſurface, as ſuppoſe the mouth of the *Ganges* in the *Eaſt-Indies*. To an eye placed in the center of the Earth at E, the center of *Venus* will be ſeen to enter on the Sun's diſk at A, when the Planet is at K in her own Orbit. But to an eye placed at C, at the ſame time, the Planet will appear ſhort of the Sun, in the line CKD; therefore by the motion of the Earth round its own axis, the place C muſt advance as far as R, while, in the mean time, the Planet, in its own Orbit, will have deſcribed the Arch KH.

But the Angle DKA, by which the center of *Venus* is ſhort of the Sun's limb, when to an eye placed in the center of the Earth it would appear to touch it, is, by calculation, = 23″. But the horary motion of *Venus*, at the time of this conjunction, is about 4′ or 240″, and 1^{h} is = 3600″. Therefore ſay,

$$240'' : 3600'' :: 23'' : 345'' = 5' 45''.$$

Venus, therefore, will deſcribe the Arch KH in 5′ 45″ of time.

When the place C comes to M, *Venus* will appear in conjunction with the Sun. And as the time before the conjunction, reckoned at C, is equal to the time after the conjunction, as reckoned at the ſame place,

when the center of *Venus*, viewed from the center of the Earth, will be ſeen leaving the Sun's diſk at B, the place C will be arrived, by the motion of the Earth round its axis, at F, at the ſame diſtance from M on this ſide, as C was on the other.

But an eye placed at F will ſee the center of *Venus* L to have already quitted the diſk of the Sun, and to appear in the Heavens at G. *Venus*'s center, therefore, will be ſeen upon the edge of the Sun ſomething ſooner than this, when the place C is arrived only at T, and the Planet herſelf at I, ſhort of L, by the Arch in her Orbit IL.

The Parallax of *Venus*, or the Angle BLG, is now = 22″. Therefore ſay,

240″ : 3600″ : : 22″ : 330″ = 5′ 30″.

To an eye placed in the center of the Earth at reſt, therefore, *Venus* will appear upon the body of the Sun all the time ſhe is deſcribing the Arch of her own Orbit KL.

But to an eye upon the Earth's ſurface at C, revolving about the Earth's axis to F, *Venus* will appear upon the Sun's diſk only while the place C revolves from R to T, and while *Venus*, in the mean time, deſcribes the Arch of her own Orbit HI.

Therefore, on account of this Parallax of Longitude, the time of the tranſit will be contracted, at the beginning, 5′ 45″
At the end - - 5′ 30″
The whole contraction, therefore, on account of the Parallax, is = 11′ 15″

What is ſaid of the place C muſt be underſtood, in a like manner, of any other place; only the contractions, on account of the Parallax, will be different at different places*.

After what has been ſaid on the tranſit of *Venus* over the Sun, which may be called a *partial* Eclipſe of that luminary, it will be of the ſame nature with the ſubject in hand, to add ſomething here in the general,

concerning ECLIPSES

of the *Sun* and *Moon*. For when theſe are underſtood, the Eclipſes of *Jupiter*'s Moons, or Satellites, will be eaſily comprehended, as being of the ſame ſort; and when this is done, we may proceed to take notice what uſe may be made of all of them in *Geography* and *Chronology*.

* See Mr. Ferguſon's Diſſert. on this Subject.

And

And firſt, then, an Eclipſe of the *Sun* is cauſed by the interpoſition of the *opake* body of the *Moon* between the *Sun* and the *Earth*. But as the *Sun* undergoes no real diminution of his light, this is, more properly ſpeaking, an Eclipſe of the *Earth*.

As the *Earth* is an opake body, and caſts a ſhadow, as all other opake bodies do, an Eclipſe of the *Moon* is cauſed by her falling into the *ſhadow* of the *Earth*. This, we have ſeen, was underſtood long ago; but from what is ſaid by *Plutarch*, in his life of *Nicias*, it appears that the doctrine of ſolar Eclipſes was but little known among the *Greeks* as late as the *Peloponneſian* war, or the year before Chriſt 431.

An Eclipſe of the *Sun* can only happen at the time of the conjunction, or at the *new Moon*. And an Eclipſe of the *Moon* can only happen at the *full Moon*, or when ſhe is in *oppoſition* to the *Sun*.

Eclipſes of the *Sun* and *Moon* are of two ſorts, either *total* or *partial*.

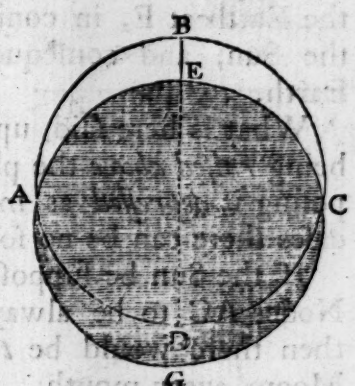
If the whole body of the *Sun* be *obſcured*, or *covered* by the whole body of the *Moon*, that is called a *total* Eclipſe of the *Sun*. If only part of the *Sun*'s body be *covered* by the *Moon*, then it is ſaid to be a *partial* Eclipſe of the *Sun*. And the more the *Sun*'s body is *covered* by the *Moon*, the greater will be the Eclipſe of the *Sun*.

Though the *Sun* and the *Moon* are *ſpherical*, yet, by reaſon of their diſtances, they appear like *flat round* ſubſtances, and are called *diſks*.

Theſe *diſks* may be ſuppoſed to be divided by a line drawn through the the center, called the *diameter* of the *diſk*. And that *diameter* may be divided into twelve equal parts, called *digits*.

In ſolar Eclipſes, the number of theſe parts covered by the opake *diſk* of the *Moon*, will be the *digits* eclipſed.

Let ABCD be the *diſk* of the *Sun*, BD its diameter divided into twelve parts, or digits. Let AECG be the opake diſk of the *Moon* covering part of the *Sun*'s luminous diſk. Here the digits eclipſed are ten.



The points A and C are called the *cups*, or *horns*. And in this caſe the *Sun* will appear horned like the *Moon*.

An Eclipſe of the *Sun* may be conſidered as *general*, or *particular*. The *general* Eclipſe will be all that time which is taken up by the ſhadow of the *Moon* in paſſing over the ſurface of the *Earth*. The *particular* Eclipſe will be all that time which an Eclipſe laſts, as ſeen at any place in particular.

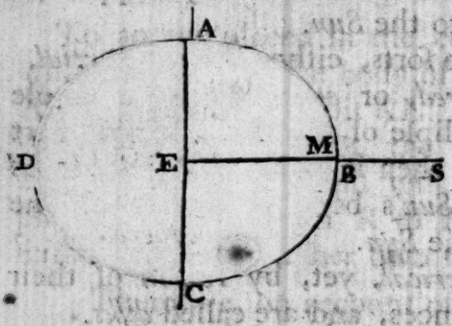
If

If ABCD be the diſk of the *Moon*, AECG a ſection of the *Earth*'s ſhadow at the diſtance of the *Moon* from the *Earth*, then that will be a *partial* Eclipſe of the *Moon*; and the digits here eclipſed will be ten.

If the diſk of the *Earth*'s ſhadow had intirely covered the *Moon*, then that would have been a *total* Eclipſe of the *Moon*.

If Eclipſes of the *Sun* and *Moon* are cauſed in the manner above related, it may be aſked, how comes it to paſs that there is not an Eclipſe of the *Sun* at every *change*, or *new Moon*, and an Eclipſe of the *Moon* at every *full Moon*, or *oppoſition*.

But this ariſes from that motion of the Moon's Nodes, which hath been mentioned before, and will be more fully conſidered hereafter.



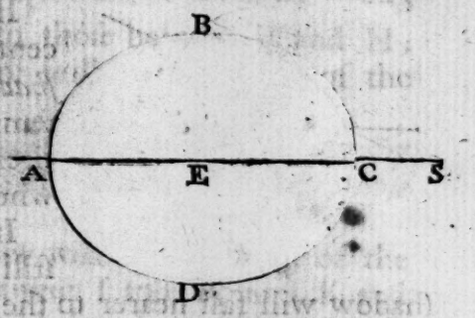
For if ABCD repreſents the plane of the Ecliptic, and the diſtance of the Sun and Moon from the Earth be ſuppoſed to be conſtantly the ſame, as likewiſe the Angle of the inclination of the Moon's Orbit, to the plane of the Ecliptic, then ſuppoſing the Sun to ſtand ſtill at S, and the line of the Nodes to be always in the poſition AC, or at a *quadrature* with the Sun, then there can never be any Eclipſe at all.

For the Earth being ſuppoſed at E, and the Moon at M, in her own Orbit, the plane of which is here repreſented by AMC, if this be lifted up above the plane of the Ecliptic, here repreſented by ABCD, making the Angle MES about five degrees, then the Moon, though ſeen from the Earth at E, in conjunction with the Sun at M, yet will be above the Sun, and conſequently will hide no part of his light from the Earth.

What is here ſaid, upon ſuppoſition of the plane of the Moon's Orbit being *raiſed above* the plane of the Ecliptic, will equally hold true, ſuppoſing it *depreſſed* as many degrees *below* that plane. So that in both caſes there can be no ſolar Eclipſe at all.

If the Sun be ſuppoſed to be at reſt at S, and the line of the Moon's Nodes AC to be always ſo too, and to lie in conjunction with the Sun, then there would be *two* Eclipſes, one of the Sun, and another of the Moon, every month.

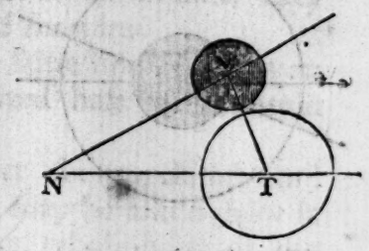
For



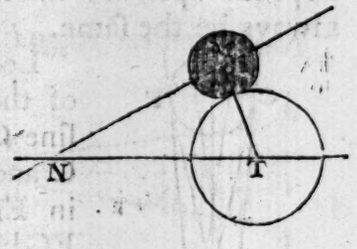
For the Earth being at E, the ſhadow of it would fall upon the Moon, now at full, at A; and the Moon, in conjunction with the Sun at C, would hide his light from the Earth at E.

No Eclipſe, therefore, of the Sun, or Moon, can happen, except when the Moon is *in*, or *near*, one or other of her Nodes, *i. e. in*, or *near*, the plane of the Ecliptic. And that ſhe is not ſo every *full* and *change*, ariſes from this motion of her Nodes.

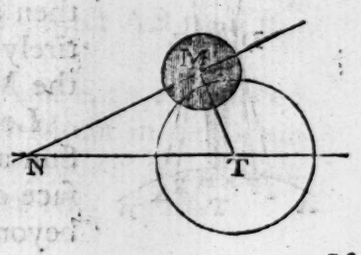
It remains, then, only to enquire within what diſtance of her Node the Moon muſt be, in order to hide any part of the Sun's light from the Earth, or to cauſe what is called an *Eclipſe* of the *Sun*.



Let T be the diſk of the Earth, M the Moon's ſhadow at the diſtance of the Earth from the Moon, MN a portion of the path of the ſhadow MT, perpendicular to MN, the neareſt approach of the centers of the Earth's *diſk* and the Moon's *ſhadow*. Then if the line MT exceeds the ſum of the ſemidiameters of the Earth's diſk, and the Moon's ſhadow, it is plain the ſhadow will not touch the Earth, and conſequently the Sun will *not* be eclipſed at all.

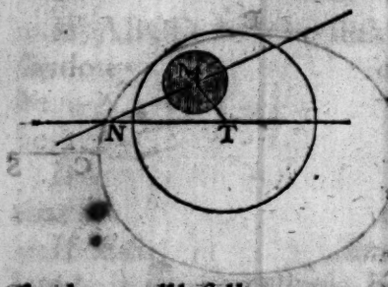


The lines continuing the ſame as before, if now the line joining the centers of the Earth's *diſk*, and the Moon's *ſhadow*, at the diſtance of the Earth from the Moon, be juſt equal to the ſum of their ſemidiameters, it is plain the ſhadow of the Moon will but juſt touch the Earth; but the Moon will hide no part of the Sun's light from any of the Earth's inhabitants.



If, at the time of the neareſt approach of theſe centers, the line MT is leſs than the ſum of the ſemidiameters of the Earth's *diſk*, and the Moon's *ſhadow*, the Moon will hide ſome part of the Sun's light, her ſhadow falling upon the Earth, to whoſe inhabitants, ſome where or other, the Sun will be *partially* eclipſed.

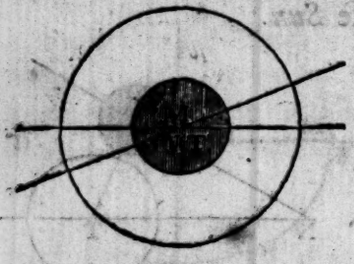
If



If the line MT, the neareſt approach of the centers of the Earth's *diſk*, and the Moon's *ſhadow*, be equal to the *difference* between their ſemidiameters, the Moon's *ſhadow* will fall intirely upon the Earth, and there will be, ſome where or other, a *total Eclipſe* of the Sun.

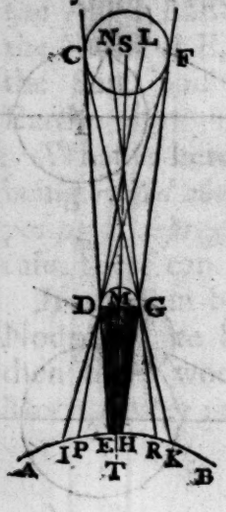
If the diſtance between the centers MT be ſtill leſs, as here, the center of the Moon's ſhadow will fall nearer to the center of the Earth's diſk; the time of the ſhadow's paſſing over the diſk will be the longer, and conſequently the *general Eclipſe* will be the greater.

The greatneſs of the Eclipſe, as ſeen at any particular place, depends upon other circumſtances.



If the three points M, N, and T, coincide, *i. e.* if the Moon be *in* her Node itſelf, the center of the ſhadow will paſs over the center of the Earth's diſk, and the *general Eclipſe* will be the *greateſt* poſſible.

This diſk of the Earth is a Circle, whoſe radius, or ſemidiameter, is the difference between the horizontal Parallaxes of the Sun and Moon. The Sun's horizontal Parallax is eſtimated, by Sir *Iſaac Newton*, at 10 ſeconds of a degree. The diſtance of the Moon from the Earth is continually changing, and therefore ſo is her horizontal Parallax, which depends upon it; the ſemidiameter of the Earth's diſk, therefore, will not always be the ſame.



Let S be the Sun, M the Moon, and AB a portion of the Earth's ſurface. Let there be drawn the right line CDE, touching the Sun and Moon in the points C and D, and meeting with the ſurface of the Earth in E. Let there be drawn, likewiſe, the right line FGH, touching the Sun and Moon in the points F and G, and meeting with the ſurface of the Earth in H; then all thoſe places that lie between E and H will intirely loſe ſight of the Sun S, by the interpoſition of the Moon M, and there the Eclipſe will be *total*.

Let there be drawn the right line FDI, touching the Sun and Moon in F and D, and meeting with the ſurface of the Earth in I; then all thoſe people that live beyond I, towards A, will ſee the whole body of the Sun

Sun at the ſame time that he is *totally* hid to thoſe between E and H; that is, to thoſe beyond I, towards A, there will be *no Eclipſe* of the Sun at all.

If we draw the line CGK, what hath been ſaid here will equally hold true of ſuch as live beyond K, towards B, who will ſee *no Eclipſe* of the Sun likewiſe.

But if we draw the lines LDP, NGR, they will cut off parts of the Sun's body; and therefore to ſuch as live between I and P, and K and R, the Sun will appear *partially* eclipſed. And the nearer the points P and R fall to E and H, the more will the Sun appear eclipſed.

All thoſe places, therefore, on the Earth's ſurface, that lie between E and I, and between H and K, will be more and more enlightened the nearer they lie towards I and K.

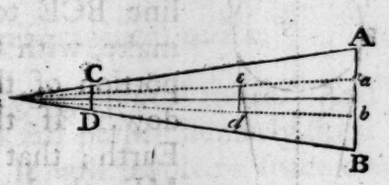
If the lines FDI, CGK, revolve about the line SMT as an axis, they will form a Cone, which is called the *Cone of the Penumbra*.

And if the lines CDE, FGH, revolve about the ſame line SMT as an axis, they will form a *truncate* Cone, whoſe inverted baſe will contain all thoſe places that are involved in the *total ſhade*.

If *Eclipſes* of the *Sun* are cauſed in the manner above related, and the *Moon's body* is ſo much leſs than the *Sun*'s, it may be aſked how it comes to paſs that ſhe is able to hide from us the whole body of the Sun. And this gives the following

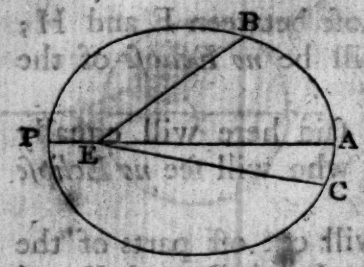
PROPOSITION IX.

The apparent diameters of objects are as the Angles under which they are ſeen.



From whence it will follow, that if a ſmaller object, as CD, be ſeen by the eye at E, under the ſame Angle AEB, with the much larger object AB, it will intirely cover it. But if the ſame object be removed into the ſituation *ed*, at a greater diſtance from the Eye, ſo as to be ſeen only under the Angle *a*E*b*, it will hide no more of the object AB than the part *ab*.

If, therefore, AB is the Sun, and CD the Moon, and E an eye placed upon the Earth, viewing the centers of the Sun and Moon in the ſame right line, the Moon will, in the former caſe, *intirely* cover the whole body of the Sun, but, in the latter caſe, it will cover only a part.



Since, therefore, the Orbit of the Moon is *elliptical*, or *oval*, as hath been ſaid, having the Earth in one of its *foci*, as E, it is plain, that, in different parts of her Orbit, ſhe will be at different diſtances from the Earth.

At A ſhe will be in her *Apogee*, or at her *greateſt* diſtance from the Earth, where her apparent diameter will be the *leaſt*. And at P ſhe will be in her *Perigee*, or at her *neareſt* diſtance from the Earth, where her apparent diameter will be the *greateſt*.

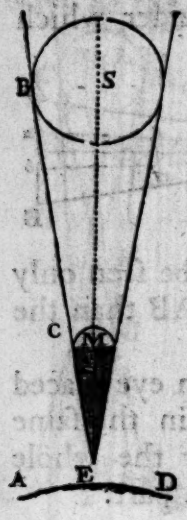
And ſince the Moon may be in conjunction with the Sun in any part of her Orbit, as A, B, P, C, it is plain that her diſtance from the Earth, at that time, may be different, and conſequently, her *apparent* diameter different. If, therefore, that diameter ſhould appear under a leſs Angle than that of the Sun, it is evident, from the laſt Propoſition, that the Moon will not cover the whole body of the Sun, which, therefore, will ſeem like a ring of light ſurrounding the body of the Moon.

Such Eclipſes as theſe are called



ANNULAR ECLIPSES.

In ſuch Eclipſes as theſe the ſhadow of the Moon doth not reach the Earth, as will be eaſily underſtood by the following conſiderations.

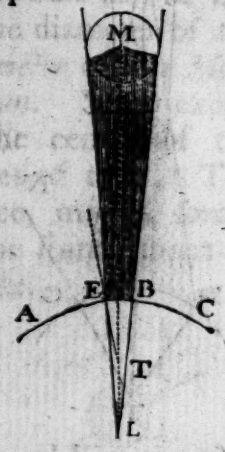


Let S be the center of the Sun, M the center of the Moon, SME the axis of the Moon's ſhadow. Let the line BCE touch the ſurfaces of the Sun and Moon, and make, with the axis SME, the Angle BES. Let AD be a portion of the Earth's ſurface receiving the Moon's ſhadow. If the Sun be at his greateſt diſtance from the Earth; that is, the Earth be in its *aphelion*, then the line ME, the length of the Moon's ſhadow, will be about 60 ſemidiameters of the Earth. But the mean diſtance of the Moon from the Earth is but about 60 ſemidiameters of the Earth; therefore, if when the Sun is at, or near, his greateſt diſtance from the Earth, the Moon, in conjuction with him, ſhould be at a greater diſtance from the Earth than her mean diſtance, it is plain that her ſhadow will not reach the Earth.

What

What is here ſaid is ſufficient to ſhew the poſſibility of the thing, without entering into all the variety of caſes that may happen.

If we could know how much of the Earth's ſurface is involved in the Moon's *total* ſhade, let M be the center of the Moon, and T the center of the Earth, of which AEBC will be a portion.



By what hath been already ſaid, all that ſpace comprehended between E, B, will be involved in the *total* ſhade.

That we may not trouble ourſelves with a variety of caſes, let us ſuppoſe LM, as above, to be 60 ſemidiameters of the Earth; and let us ſuppoſe, farther, the diſtance of the Moon from the center of the Earth to be her leaſt diſtance; that is, about 56 ſemidiameters. Therefore, it will be, TE : TL : : 1 : 4.

In this diſtance of the Sun from the Earth, the Angle TLE is about 15′ 50″. Therefore, by what was obſerved long ago †, it will be,

TE : TL : : 1 : 4 : : Sine 15′ 50″ : Sine 1° 3′ 20″ = TEL.

But the Angle ETM is the external Angle of the Triangle ETL, and therefore * equal to the two internal Angles TEL and TLE; and therefore, in this caſe, equal 1° 19′ 10″, the double of which will be the Angle ETB = 2° 38′ 20″, the meaſure of which is the Arch of the Earth's periphery EB.

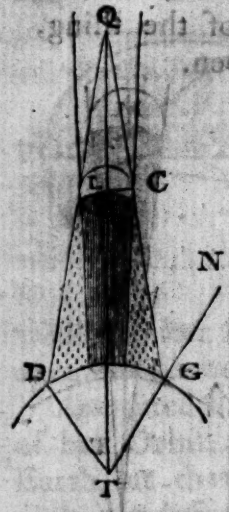
But in 1° are 3600″, which correſpond to 60 geographical miles; and 2° 38′ 20″ are equal to 9500″. And therefore it will be

3600″ : 60 miles : : 9500″ : 158,3 geographical miles.

The Arch EB, therefore, will be equal to 158 geographical miles. And if we ſuppoſe the *Cone* of the Moon's ſhadow to fall perpendicularly upon the Earth, and revolve about ML, as an axis, it will involve a ſpace on the Earth's ſurface, included within a Circle, whoſe Radius will be about 79 geographical miles.

In much the ſame manner may the ſpace on the Earth's ſurface, involved in the *whole Shade*, or the *Penumbra*, be found.

† Prop. iv. p. 6. * Elem. lib. i. prop. 32.



Let L be the center of the Moon, and T the center of the Earth, DQG the Angle of the Cone of the *Penumbra*.

Let us ſuppoſe the apparent ſemidiameter of the Sun the greateſt that can be, which is about 16′ 23″; this, likewiſe, will be equal to the ſemiangle of the Cone of the *Penumbra*, or TQG.

Then drawing the ſemidiameter of the Moon LC, perpendicular to CQ, and calling it (1) Unity, and making QL Radius, it will be

Sine 16′ 23″ : Radius :: 1 : QL = 209,8 ſemidiameters of the Moon.

But the ſemidiameter of the Moon is to the ſemidiameter of the Earth, nearly, as 28 to 100. Therefore it will be 100 : 28 :: 209,8 : 58,7; that is, QL will be equal to 58,7 ſemidiameters of the Earth.

Suppoſe now the Moon to be at her greateſt diſtance from the Earth; then will TL be about 64 ſemidiameters of the Earth, to which if we add QL = 58,7, we ſhall have QT = 122,7 ſemidiameters of the Earth. Then in the Triangle QGT, it will be

TG : QT :: 1 : 122,7 :: Sine TQG : Sine TGQ,

or its complement

QGN :: Sine 16′ 23″ : Sine 35° 42′ 23″.

But this being the external Angle of the Triangle TQG, and therefore equal to the two internal ones, if we take from it the Angle TQG = 16′ 23″, we ſhall have the Angle QTG = 35° 26′, the double of which is the Angle DTG = 70° 52′, the meaſure of which is the Arch on the Earth's ſurface DG.

Then ſince 70° 52′ is equal to 4252′, and 1° is equal to 60′, it will be

60′ : 60 geographical miles :: 4252′ : 4552 geographical miles

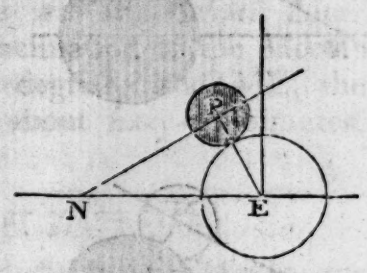
contained in the Arch DG; this, therefore, will comprehend all that ſpace on the Earth's ſurface within which the Sun will appear eclipſed.

Both the total ſhadow, and the *Penumbra*, have been ſuppoſed hitherto to form Circles on the Earth's ſurface. But this is not ſtrictly true; for as they fall, at different places, with different obliquity, they will make *Ovals*, or *Ellipſes*, of different ſpecies.

What hath hitherto been obſerved on ſolar Eclipſes, is only in general, and with reſpect to the paſſage of the Moon's ſhadow over the intire

tire disk of the Earth. But with regard to particular places on the Earth, it must be remarked, that total Eclipses of the Sun can be nowhere of any long duration. The reason is, because the diameter of the total shade is never but very small, the *apparent diameter* of the *Moon* not much exceeding the *apparent diameter* of the *Sun*. That excess seldom amounts to two minutes, and that space the center of the shade will pass over on the Earth's disk in four minutes of time. The stay, however, that it may make at any particular place, may be somewhat longer than this; because, by the rotation of the Earth about its own axis, the place follows or goes along with the shade.

Let E be the center of the Earth's disk, P the center of the Moon's *Penumbra*, at the distance of the Earth from the Moon, PE the nearest approach of those centers, and PN the distance of the center of the *Penumbra* from the Ecliptic.



The Angle PNE will be the Angle of the Moon's way with the Ecliptic, which, when biggest, is about $5^{\circ}\ 30'$. Therefore N will represent the Moon's Node; PE, when biggest, will be about $1^{\circ}\ 34'\ 30''$, or $94'\frac{1}{2}$; therefore in the right-angled Triangle PNE it will be,

$$\text{Sine PNE } (5^{\circ}\ 30') : \text{Rad.} :: \text{PE } (94'\tfrac{1}{2}) : \text{NE} = 985',9,$$

or, in round numbers, $986' = 16^{\circ}\ 26'$.

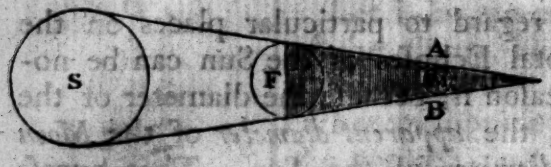
Unless, therefore, at the time of the conjunction, the Moon be within $16^{\circ}\ 26'$ of the Node, the *Penumbra* will not touch the Earth; and consequently there will be *no Eclipse* of the Sun at all. This $16^{\circ}\ 26'$, for *solar Eclipses*, is called the

ECLIPTIC LIMIT.

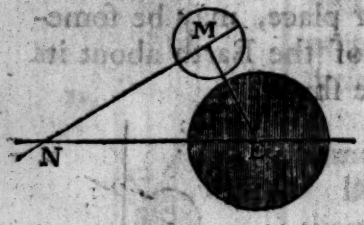
After what hath been said upon *solar Eclipses*, it will not be difficult to understand what is to follow upon

LUNAR ECLIPSES.

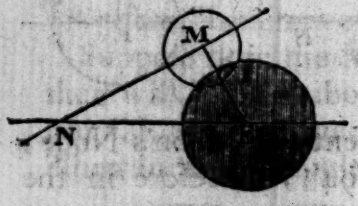
For as the *former* were caused by the *Moon's shadow* falling upon the *disk* of the *Earth*, so *lunar Eclipses* are caused by the *Earth's shadow* falling upon



upon the *diſc* of the *Moon*, as here repreſented; where S is the Sun, F the Earth, and M the Moon, fallen into the ſhadow of the Earth. AB is the diameter of the ſhadow of the Earth, at the diſtance of the Moon from the Earth.

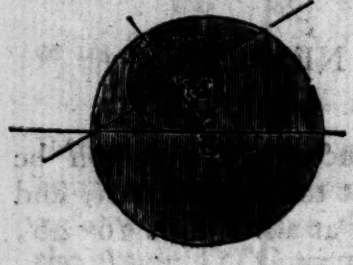


Let now M be the Moon, E the *Earth's ſhadow* at the diſtance of the Moon from the Earth, at the time of the oppoſition, or full Moon, and N the Node, and ME the neareſt approach of the Moon's center to the center of the Earth's ſhadow there; it is plain that if ME exceeds the ſum of the ſemidiameters of the Moon and the Earth's ſhadow, there will be *no Eclipſe* of the *Moon* at all.



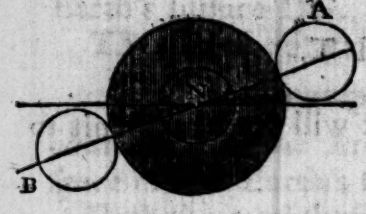
But if ME is leſs than the ſum of thoſe ſemidiameters, then that *Eclipſe* will be

PARTIAL.



But if ME is leſs than the *difference* between thoſe ſemidiameters, then that Eclipſe will be

TOTAL.



If, at the time of the *oppoſition*, the Moon is in the Node itſelf, then the Eclipſe will be

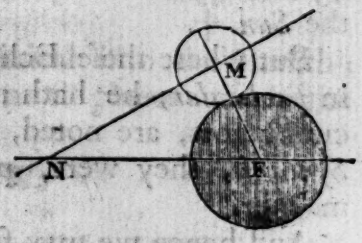
TOTAL AND CENTRAL,

and its duration the longeſt poſſible.

The longeſt that any *Eclipſe* of the *Moon* can laſt, is while ſhe deſcribes ſuch an Arch as AB, which is equal to four of her diameters, or about two degrees. But this ſpace the Moon commonly deſcribes in about four honrs time.

Since

Since the Moon can only touch the ſhadow of the Earth, without falling into it, when the center of the ſhadow is at one particular diſtance from her Node, as NE, it will be found, by calculation, that the diſtance NE cannot exceed 12° 37′. And this, for *lunar Eclipſes*, is called the



ECLIPTIC LIMIT.

This diſtance is found in the ſame manner as was the *Ecliptic Limit* for ſolar Eclipſes. For the Angle MNE, the inclination of the Moon's way to the Ecliptic, may be eſtimated at five degrees; and ME, the neareſt approach of the centers, will then be about ſixty-ſix minutes. Then it will be

Sine 5° : Radius :: 66′ : 757′ = 12° 37′ = NE.

And now, from what hath been ſaid on this doctrine of Eclipſes, we may obſerve, that as *ſolar Eclipſes* are cauſed by the ſhadow of the Moon falling on the diſk of the Earth, but *lunar Eclipſes* by the Moon receiving the diſk of the Earth's ſhadow, at her diſtance from the Earth, *i. e.* by paſſing through the cone of the Earth's ſhadow there; and ſince the *diſk of the Earth*, in the former caſe, is *much broader* than the diſk of the Earth's ſhadow in the latter caſe, it will follow, that the ſhadow of the Moon will fall *more frequently* on the *broader* diſk of the Earth, than the Moon *herſelf*, ſo much leſs than the Earth, can receive the *narrower* diſk of the Earth's ſhadow.

There will, therefore, in *general*, be more *Eclipſes* of the *Sun* than of the *Moon*. And yet, with reſpect to any given place in *particular*, there will be *more Eclipſes* of the *Moon* than of the *Sun*; which is juſt the contrary.

The reaſon is, that *Eclipſes* of the *Moon* are viſible to all places where the Moon is *above the Horizon*. But this doth not hold good with regard to *Eclipſes* of the *Sun*; for an *Eclipſe* of the *Sun* may be *viſible* at *one* place, and *inviſible* at another, though the Sun is *above* the Horizon of both places. This depends on the Moon's *Latitude* at the time of the *viſible* conjunction at thoſe places, and the *Parallax*, which, as we have ſeen, *depreſſes* her in the perpendicular.

Hence we ſee a reaſon why *Diogenes Laertius* may be credited, when he tells us, that during the ſame time that the *Egyptians* had obſerved

832 *Eclipſes* of the *Moon*, they had obſerved only 373 *Eclipſes* of the *Sun* †.

But where theſe Eclipſes were obſerved, or whether at any one place, in *particular*, he hath not ſaid. And as neither times, nor other circumſtances, are noted, nor any mention is made of them in *Ptolemy's Syntaxis*, they were, probably, ſet down in a very rude and imperfect manner.

And hence we may form the two following general

PROBLEMS.

The day of the month, and the hour of the night, being given, to find all thoſe places on the Globe where any *lunar* Eclipſe will be viſible.

The day of the month being given, the *Sun's place* will be found on the wooden Horizon, and conſequently his *declination* on the braſs Meridian. Bring that point of the Sun's declination into the Vertex; then will the wooden Horizon repreſent the Circle bounding light and darkneſs in the *Copernican* hypotheſis.

II. Bring the place for which the time is given (ſuppoſe *London*) to the Meridian, and ſet the hour-index to the hour given. Turn the Globe till the hour-index points to twelve at noon, then will the Sun be vertical there, and all thoſe places that lie under the Horizon will ſee that *Eclipſe* of the *Moon*; or bringing the Antipodes to the place where the Sun is vertical into the Zenith, all thoſe places, where the Eclipſe will be viſible, will then lie above the Horizon.

NOTE,

becauſe lunar Eclipſes continue ſometimes for a long while together, they may be ſeen in more places than in one Hemiſphere of the Earth; for by the Earth's rotation about her own axis, during the time of the Eclipſe, the Moon will riſe in ſeveral places, after the Eclipſe hath begun.

PROBLEM.

The day of the month, and the hour of the day, being given, to find all thoſe places upon the Globe where a *ſolar Eclipſe* will be viſible, if it be a central one.

† Proem. ad vit. Philoſoph.

Find,

Find, as in the laſt Problem, the Sun's place, his declination, and the place where he is vertical at the given hour.

Bring the place to which the Sun is then vertical into the Zenith; then ſome part of the Eclipſe will be viſible in moſt places within the *upper Hemiſphere*.

N O T E,

by reaſon of the ſhort duration of ſolar Eclipſes, and the *Latitude* which the *Moon* commonly hath at that time (however ſmall) there is no certainty in determining the places where ſuch *ſolar Eclipſes* will be viſible by the Globe; but recourſe muſt be had to calculation.

As *Eclipſes* of the *Sun* are cauſed by the *Moon* paſſing between him and the *Earth*, and *Eclipſes* of the *Moon* by her falling into the ſhadow of the *Earth*, as already explained, ſo it is evident, that when one of *Jupiter's Moons*, or *Satellites*, paſſes between the *Sun* and *his body*, there will be an *Eclipſe* of the *Sun* to the inhabitants of *Jupiter*.

And again, when one of his *Moons*, or *Satellites*, falls into his ſhadow, that *Satellite* will be eclipſed, as was obſerved before of our *Moon*.

Under this head of *Eclipſes*, then, and conſidering the Uſes that are made of *Eclipſes* of theſe *Satellites* in finding the Longitude of places, it will not be foreign to the ſubject, to introduce here the following

P R O B L E M.

The day and the hour of an *Eclipſe* of any one of *Jupiter*'s Satellites being given, to find upon the Globe all thoſe places where it will be viſible.

The day being given, the Sun's place and declination will be given. Bring that point of declination into the Vertex; then will the wooden Horizon repreſent the Circle bounding light and darkneſs, according to the *Copernican* hypotheſis, as before.

Bring the place for which the hour is given (ſuppoſe *London*) to the Meridian, and ſet the hour-index to the given hour.

Turn the Globe till the hour-index points to twelve at noon; then to all thoſe places that lie on the edge of the eaſtern Horizon the Sun will be ſetting. Mark thoſe places, by drawing a line with chalk, or a black lead pencil, over them.

If *Jupiter* be in conſequence of the Sun, he will ſet after the Sun; therefore find the declination of *Jupiter*, and elevate the Globe for his declination, as was done before for the Sun's.

Count the difference between the right aſcenſion of the Sun and *Jupiter*, allowing 15 degrees to an hour. Then turn the Globe weſtward, till the hour-index points to that difference of right aſcenſion, and drawing a line, as before, along the eaſtern ſide of the Horizon, that will paſs over all thoſe places to which *Jupiter* will be ſetting. Therefore the ſpace comprehended between the two lines, will include all thoſe places where *Jupiter* will be viſible from the ſetting of the Sun till the time of *Jupiter*'s ſetting; and conſequently, all thoſe places, where that Eclipſe of his Satellite, will be viſible.

If *Jupiter* be in antecedence of the Sun, he will riſe before him, and therefore ſet before him. For which reaſon, find the declination of the Sun and *Jupiter*, as before, and elevate the Globe accordingly; find, likewiſe, the places to which they will be vertical, as before, only draw the lines on the weſtern ſide of the Horizon; then thoſe lines will include all that ſpace within which *Jupiter* will be viſible between the time of his riſing and that of the Sun; and conſequently all thoſe places where that Eclipſe of his Satellite will be viſible in the Morning.

EXAMPLE.

This year 1766, *June* 25 at noon, we have the

Sun's place - - - - - *Cancer*	3°	46′	30″
The Sun's declination North - - - -	23	25	00
Jupiter's place - - - - - *Leo*	20	29	00
Jupiter's declination North - - - -	15	32	00
Sun's right aſcenſion - - - - -	90	46	30
Jupiter's right aſcenſion - - - - -	142	30	00
Difference - - - - -	51	43	30

This difference gives, in time, 3^h 27′ nearly.
Elevate the Globe for the Sun's declination 23° 25′.

Then will the wooden Horizon repreſent the Circle bounding light and darkneſs. Suppoſe the time of an emerſion of *Jupiter*'s firſt Satellite to be at nine o'clock. Bring up *London* to the braſs Meridian, and ſet the hour-index to nine. Turn the Globe, till the hour-index points to twelve at noon; then will the Sun be vertical to ſome place in the *Pacific Ocean*, and he will be ſetting to all thoſe places that lie in the edge of the eaſtern Horizon, as to *Terra Magellanica*, *Paraguay*, the *Brazils*, *Ireland*, and the South of *Scotland*.

Elevate

Elevate the Globe for 15° 32′ *Jupiter*'s declination; and becauſe he is in *conſequence* of the Sun, and therefore ſets after him, turn the Globe weſtwards, till the hour-index points to the difference of right aſcenſion, before found 3ʰ 27′. Then draw a line along the edge of the eaſtern Horizon, and that will paſs over all thoſe places to which *Jupiter* will be ſetting, as the *Ethiopic Sea*, the coaſt of *Africa*, to the Eaſt of *Sicily* and *Italy*, and the entrance into the *Gulph of Venice*.

And all the ſpace comprehended between theſe two lines will include all the places where this emerſion of *Jupiter*'s Satellite would be viſible.

Having ſeen the nature of Eclipſes in general, it will be proper, in the next place, to take ſome notice of the *Uſes* to which they may be applied; and theſe will be principally two.

I. With reſpect to CHRONOLOGY.
II. With reſpect to GEOGRAPHY.

As to the firſt of theſe, it may be obſerved, that nothing can fix the date of ancient tranſactions with ſo much accuracy as Eclipſes of the Sun and Moon, whenever they can be had.

We ſaw before in what manner the concluſion of the war between the *Lydians* and *Medes* is fixed, by the ſolar Eclipſe foretold by *Thales*, to the year before Chriſt 603.

It is by means of a lunar Eclipſe that there is diſcovered a miſtake in placing the vulgar *Æra* of CHRIST.

For it is well known that Chriſt was born whilſt *Herod* was king of *Judea*. But *Joſephus* ſays *, that there was, juſt before the death of *Herod*, an Eclipſe of the Moon, and this Eclipſe was in the night between the 12th and 13th of *March*, and in the 4th year before the vulgar Chriſtian Æra. This Æra, therefore, ought to be carried back, as it appears, *three* whole years at leaſt.

Again, it is well known from *Herodotus* †, that when *Xerxes* marched from *Sardis*, in his expedition againſt *Greece*, there was a very great ſolar Eclipſe; that this terrified the army, who looked upon it as an ill omen of their ſucceſs; that *Pytheas*, who had a ſon in that army, begged of *Xerxes* that he might be diſmiſſed from ſerving any longer; that *Xerxes* not only refuſed the requeſt, but likewiſe ordered the young man to be cut in pieces, and that the army ſhould march between the parts of the body.

* Antiq. lib. xvii. cap. 6. † Page 395.

These are circumstances most remarkable in their kind, and could not but be well known at the time, by *Herodotus* in particular. The fact, therefore, is as certain as any historical evidence can make it.

This expedition of *Xerxes* is commonly fixed by the *technical Chronology*, that is, by comparing together the *Olympiads*, *Consular Fasti*, and the *Athenian Archons*, to the year before Christ 480.

And yet it is certain, that in the year before Christ 480 there was no solar Eclipse at all in the spring.

But the Chronology by *Olympiads*, *Consular Fasti*, and the like, is not so certain, but that we may venture to depart from it, when we have good grounds for so doing; and therefore, though there can be found no solar Eclipse in the spring of the year before Christ 480, yet we shall find that *two* years afterwards, or in the spring of the year before Christ 478, there was a very great *solar Eclipse*. But this Eclipse being so remarkable in its consequences, and of such importance in History, hath been considered at large in a separate Dissertation. From what hath been there said, with relation to this Eclipse, it seems evidently proved, that *Xerxes* came into *Europe* two years later than the common Chronology makes him to have done.

The only thing that can be objected to this Eclipse is, that the quantity of obscuration at *Sardis* will hardly be thought adequate enough to the effect. But there is a difficulty, it is well known, with regard to ancient Eclipses; so that their quantities, by calculation, do not always suit with the historical descriptions of them.

This difficulty ariseth from several causes, either from a defect in the tables themselves; or from that small *accelleration* in the Moon's *mean motion*, discovered first by Dr. *Halley*, and before mentioned; or, lastly, from an imperfection in the *Geography* of the *East*. For though there are many catalogues of places to be met with, as those of *Ptolemy*, *Abulfeda*, and *Nassir Eddin Ettusi*, in which their *Longitudes* and *Latitudes* are set down, yet none of them are so exact as to be fully depended on.

Smyrna is better known than *Sardis*, and lies nearly in the same Latitude with it; that is, in 38° 28′ 7″; and in time, to the East of *Greenwich*, as set down in Dr. *Halley*'s tables, 1^h 49′ 19″ By another calculation, therefore, by his tables, there will be given the following elements.

Time of the mean conjunction at *Greenwich* -	22^h 25′ 38″
Equation of time - - - -	17 05
Apparent time of the conjunction at *Greenwich* -	22^h 08′ 33″

Place

Place of the Luminaries	10ˢ	22°	51′ 00″
Sun's declination South		13	55 29
Moon's Latitude North			44 30
Inclination of Moon's way		5	13 49
Moon's horizontal Parallax			54 32
Semidiameter of the Earth's diſk			54 20
Sun's ſemidiameter			16 07
Moon's ſemidiameter			14 59
Semidiameter of the Penumbra			31 06
Sun's horary motion from the Sun			28 08
Longitude of *Smyrna* from *Greenwich*		27°	19′ 45″
Latitude of *Smyrna* North		38	28 07

And by conſtructing this Eclipſe from theſe elements, we ſhall find the time of the apparent conjunction at *Smyrna* to have been at 35′ paſt 12 at noon, and the digits eclipſed 11¼. And this agrees very well with the circumſtances of the Hiſtory.

Having in this manner rectified, by Eclipſes, one or two chronological errors, it may not be amiſs to take notice of one hiſtorical fact more, that may be eaſily cleared up, and aſcertained, by another.

Every one knows that *Herodotus*, and moſt of the ancient Hiſtorians, ſay, that *Cyrus* made war upon, and conquered, his grandfather *Aſtyages*, and ſo turned the empire from the *Medes* to the *Perſians*.

On the contrary, *Xenophon* ſays *, that *Aſtyages* died in *Media*, and left the crown to his ſon *Cyaxares*; and that *Cyaxares*, having no *legitimate ſons*, gave *Media*, as a portion with his daughter, to *Cyrus*, his ſiſter's ſon †.

Theſe two accounts ſeem not reconcilable with each other, and yet the truth may lie, perhaps, between both. *Aſtyages* might die a natural death in *Media*, and therefore was not conquered by *Cyrus*; contrary to what *Herodotus* ſays. *Xenophon* doth not ſay, that *Cyaxares* did not afterwards *repent* of his donation to his nephew, and endeavour to take it from him, and in the event was conquered by him. That *Xenophon*, however, knew that the *Perſians* came to the empire by *conqueſt*, is certain, notwithſtanding he thought proper, in his *Cyropædia*, to *conceal* and *diſguiſe* it.

For in his *Anabaſis*, which is nothing more than the *Journal* of a *March*, and where things are related juſt as they were found, he ſays, that when they came down to the banks of the *Tigris*, they found a *large*,

* Cyropæd. p. 57. Edit. Oxon. 1727. † Ibid. p. 631.

but

but *deserted* city, called *Larissa*, formerly inhabited by the *Medes*. "This (continues he) the KING of the *Persians* laid siege to at the "time when they *took* the empire from the *Medes*; but was not able, "by any method, to make himself master of it. At last, however, a "*Cloud* coming over the *Sun*, made it disappear, in such a manner, "that the hearts of the inhabitants failed them, and so it was "taken *."

The remarks to be made upon this passage are, 1st, That when *Xenophon* asked the people on the spot what *ruins* these were? they probably answered him, לרסן *Laresen*, *i. e.* the *ruins of Resen*: that he took this for one word, and for the name of the *city*, which he altered in his journal for *Larissa*, a name that he was more familiarly acquainted with.

2dly, That though he calls it a *Cloud* that covered the Sun, yet, probably, his informers called it ענן *Anan*, which signifies any obstacle in general.

3dly, That it is very improbable that any *ordinary Cloud* could be the cause of so remarkable an event; and therefore, the body of the Moon, intercepting the light of the Sun, at a time when the doctrine of *solar Eclipses* was but little understood, might properly enough be stiled ענן *Anan*, or an *obstacle*, and a *Cloud* is nothing more.

4thly, That from a number of arguments, too long to be insisted on here, and which would require a dissertation in particular, it appears, that *Cyrus* finished his reduction of the *Median* empire the year before Christ 547; and that this year there was a very great *solar Eclipse*, and that the center of the shadow crossed the *Tigris*, not far from the place where *Xenophon*'s *Larissa* was probably situated.

The apparent time of the true conjunction at *Greenwich* was *October*	-	-	-	-	$21^d\ 23^h\ 39'\ 18''$	
And the place of the Luminaries	-	-	-		$6^s\ 24^\circ\ 9'\ 00''$	
Moon's Latitude North	-	-	-	-	-	$46'\ 24''$
Moon's semidiameter	-	-	-	-	-	$16'\ 50''$
Sun's semidiameter	-	-	-	-	-	$16'\ 21''$

The farther particulars relating to this Eclipse I have formerly treated of in the *Philosophical Transactions* more at large †.

Having seen what use may be made of *Eclipses* in *Chronology*, we may now proceed to observe of what importance they are in *Geography*. And this naturally leads us to consider the famous Problem,

* P. 237. Edit. Oxon. 4to.

† Vol. xlviii. Part. i.

without

without which the art of Navigation can never be brought to perfection; and that is, for determining the

LONGITUDE OF PLACES.

What is meant by the Longitude of Places, hath been ſeen already. And in what manner the Longitudes of Places, once known, are found by the terreſtrial Globe, needs but little explication. The queſtion is, how to find the Longitude of Places, in order to the marking them down in Maps, or on Globes.

This is the grand Problem ſo much talk'd of, and, in general, ſo little underſtood; and conſiſts only in finding the difference between the Meridians paſſing through any two given places, reckoned in Arches of the equinoctial Circle.

The nature of this Problem, then, is of two Sorts.

I. To find the Longitude of any place at land; or,
II. At ſea.

The difficulty of the former, as hath been ſeen already, is in a manner inconſiderable. But to find the Longitude of a ſhip at ſea, is extremely difficult. It is of ſo great conſequence to the preſervation of men's lives and ſhipping, that the Parliament of *Great-Britain* propoſed a reward of 10,000*l.* if it extended only to 1° of a great Circle, or 60 geographical miles; 15,000*l.* if found to 40 ſuch miles; and 20,000*l.* to the perſon that can find it within 30′ of a great Circle, or 30 geographical miles.

There was alſo another proviſo, That any *leſſer* diſcovery of the ſame Longitude, ſhould have a proportionably leſſer Reward. All which was to be determined by Commiſſioners, named in the Act.

Of what uſe it is to know the Longitude of places at ſea, may be ſeen in the following inſtance. The Editor of Lord *Anſon*'s Voyage, ſpeaking of the Iſland of *Juan Fernandez*, adds, "The uncertainty we "were in of its poſition, and our ſtanding in for the main on the 28th "of *May*, in order to ſecure a ſufficient eaſting, when we were indeed "extremely near it, coſt us the lives of between 70 and 80 of our men, "by our longer continuance at ſea. From which fatal accident we "might have been exempted, had we been furniſhed with ſuch an "account of its ſituation as we could fully have depended on †."

† Page 160. Edit. 8vo.

But

But another uſe of knowing the Longitude at ſea, eſpecially in long Voyages, is to know the ſhip's Latitude. This hath been well taken notice of by Captain *Dampier* ‡.

"One great reaſon (ſays he) why ſeamen ought to keep the difference "of time as exact as they can, is, that they may be more exact in their "*Latitudes*. For our tables of the Sun's declination being calculated "for the Meridians of the places where they were made, differ about "12 minutes from thoſe parts of the World that lie on their oppoſite "Meridians, in the months of *March* and *September*, and, in propor- "tion to the Sun's declination, at other times of the year alſo. And "ſhould they run farther, as we did, the difference would ſtill increaſe "upon them, and be an occaſion of great errors.

"Yet even able ſeamen, in theſe voyages, are hardly made ſenſible of "this, though ſo neceſſary to be obſerved, for want of duly attending "to the reaſon of it, as it happened among thoſe of our own "Crew."

An example of this may not be amiſs.

Suppoſe, then, the Longitude of the place to be 120 degrees to the Eaſt from *London*. This will give eight hours in time; conſequently if it be noon there, it will be only four o'clock in the morning at *London*. Let the Sun's Meridian altitude be, by obſervation, 60 degrees, and the time be *April* 12, 1764.

Let the Sun's declination, by tables made for the Meridian of *London*, *April* the 12th at noon, be - - - - -	8° 57′
And for *April* the 11th at noon be - - - - - - -	8° 35′
The difference - - - - - - - - - - - - - -	0° 22′

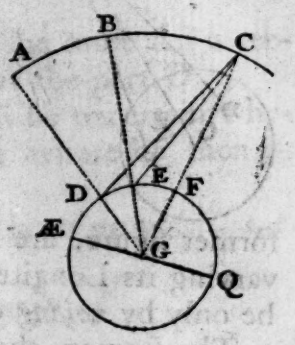
Suppoſe the Sun's motion, for that time, to be equable, then it will be, $24^h : 22' :: 8^h : 7'\ 20''$.

Then the Sun's declination, as before, - - -	8h 57′ 00″
Change in the Sun's declination for 8 hours - -	7 20
Sun's true declination - - - - -	8h 49′ 40″
Sun's Meridian altitude - - - - -	60° 00′ 00″
Sun's declination North ſubtract - - -	8 49 40
Height of the Equator there - - - -	51° 10′ 20″
The complement of which to 90° is the height of the Pole, or the Latitude of the place - - -	38° 49′ 40″

‡ Vol. i. p. 377.

Before

Before we come to ſpeak of the ſeveral methods whereby the *Longitude* hath been attempted to be found, it will not be improper to premiſe the few things following.



Let ABC be the Arch of a great Circle in the Heavens, DEF a Meridian, or correſponding great Circle on the Earth, G the center of the Earth, C the Pole Star, E the place of a ſhip; B will be the Zenith, or vertical point to that place E, and the Angle BEC the apparent diſtance of the Pole Star C from the Vertex B. Let ÆQ be the Equator.

Suppoſe now the ſhip ſails along the ſame Meridian from E to D. When arrived arrived at D, the Angle ADC will be the apparent diſtance of the Pole Star from the Vertex A.

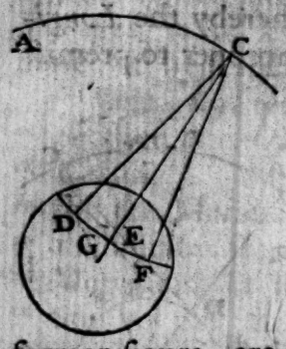
But the Angle ADC is greater than BEC; and therefore will be the greater ſtill, the nearer the place lies towards the Equator ÆQ.

The Pole Star C, therefore, will appear farther from the Vertex to a ſhip at D than to the ſame ſhip when at E, *i. e.* more *depreſſed*, or *nearer* to the Horizon. And at laſt when the ſhip arrives at Æ, the Pole Star will lie in the Horizon itſelf. For becauſe of the immenſe diſtance of the fixed Stars, the ſemidiameter of the Earth vaniſhes, or becomes = o, as hath been remarked before; ſo that it will be the ſame thing whether the Pole Star be viewed from the center of the Earth G, or from the ſurface of it at Æ.

In this obſervation conſiſted the principal art of Navigation among the ancients. Thus the pilot in *Lucan* tells *Pompey*,

---------- *hic cum mihi ſemper in altum*
Surgit, & inſtabit ſummis minor Urſa *Cheruchis*,
Boſphoron, & Scythiæ *curvantem littora Pontum*
Spectamus. Quicquid deſcendit ab arbore ſumma
Arctophylax, *propiorq; mari* cynoſura *feretur*,
In Syriæ portus tendit *ratis*.-------- *

* Lucan Pharſ. lib. viii.



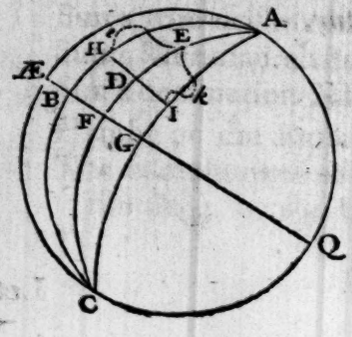
Let AC, as before, be an Arch of a great Circle in the Heavens, and C the Pole Star, G the center of the Earth, and GC the axis of the Earth produced to the fixed Stars. Let the Arch DEF be a Parallel of Latitude. Then, from the nature of a Parallel of Latitude, if a ſhip ſail from E to D, or from E to F, the diſtance of the Pole Star (C) from the Vertex of all theſe places will be the ſame.

If two given places, therefore, D and E, in the former figure, are known to lie under the ſame Meridian, a ſhip, by not varying its Longitude, will arrive from one to the other. And this will be only by *raiſing* or *depreſſing* the Pole.

The ſeaman, therefore, by knowing the diſtance of the Pole Star from the Vertex at each place, and the diſtance of the Pole Star from the Vertex at any intermediate place where he is, as E, will know his diſtance from either D or E. If then he finds himſelf to the *ſouthward* of the place he propoſed ſailing to, he will know that he muſt, without varying his Longitude, or keeping on the ſame Meridian, conſtantly raiſe the Pole, or ſail *northward*, in order to arrive there. If he finds himſelf to the *northward* of his Port, he muſt do the like, only conſtantly depreſs the Pole.

If two given places, D and E, are known to lie in the ſame Parallel of Latitude, as in the preſent figure, a ſhip, by not varying its *Latitude*, *i. e.* by not *depreſſing* or *elevating* the Pole, or changing the diſtance of the Pole Star from his Vertex, will arrive from one to the other.

But ſince, in ſailing, it ſeldom happens that places lie either under the *ſame Meridian*, or in the *ſame Parallel of Latitude*, or if they do, in long voyages eſpecially, it is impoſſible, through winds, or currents, to avoid changing both *Longitude* and *Latitude*, the nature of the Problem before us is, at *any aſſigned place* to determine its *Longitude* and *Latitude*, and conſequently to be able to mark it down in a Chart.



Let ABC, AFC, AGC, be three Meridians; and let a ſhip ſail from E, with intention to go to D, as before, lying under the *ſame Meridian*; but by winds, or currents, *&c.* let it be driven in the line E*e*H, or E*k*I, to H or I.

Let H or I be found, by obſervation, as before, to be in the ſame Parallel of Latitude with D, whoſe *Latitude* it is known; was the Longitude of H, for inſtance, likewiſe known,

or

or the distance of the Meridians ABC, AFC, measured by BF, an Arch of the Equator ÆQ, it is plain the seamen would know that he must sail to the *eastward* a certain number of leagues, or miles, which will bring him to D, the Port sought.

If he was driven to I, and his Longitude known, he must sail a certain number of leagues *westward*, in order to arrive at the port D.

But if his Longitude atH or I is *not known*, he will be uncertain whether D lies to the *eastward* or *westward* of the place where he then is. This, therefore, is the thing to be determined.

And, in order to find this, several methods have been proposed, *i. e. four* Celestial and *four* Terrestrial Methods.

1. The LOG-LINE, or DEAD-RECKONING.
2. By THROWING of SHELLS.
3. The VARIATION of the NEEDLE.
4. ECLIPSES of the MOON.
5. ECLIPSES of the SUN.
6. ECLIPSES of JUPITER's SATELLITES.
7. The MOTION of the MOON.
8. CLOCKS, or WATCHES.

Of each of these I shall say a few words.

1. By the Log-Line is to be understood, a line fastened to a piece of wood, and wound about a reel, for that purpose fixed in the gallery of a ship. This line, for about 10 fathom, or 20 yards from the log, hath, or ought to have, no knots or divisions; because so much should be allowed for the log's being clear of the eddy of the ship's wake, before the glass is turn'd up. But then the knots or divisions begin, and ought to be, at least, 50 feet from one another; though the common practice is to have them at only *seven* fathom, or 42 feet distance.

By the number of Knots running off the Reel in a given space of time, the sailors judge of the rate at which the ship sails in that time; and consequently, the number of leagues, or miles, described by her. And supposing the wind to blow uniformly, and all circumstances the same, the rate at which the ship sails may be estimated, by the common rule of proportion, for a longer time.

This, though, at best, but a precarious way, is however the most exact of any in use, and much better than that of the *Spaniards* and *Portuguese*, who guessed at the ship's way by the running of the *froth* by the ship's side; or than that of the *Dutch*, who used to throw a chip into the sea, and so

number the paces they could walk on the deck while the chip ſwam, or paſſed, between any two marks, or bolt-heads on the ſide.

The *ſecond* method for finding the Longitude, was ſaid to be by throwing of *Bombs*, and their exploſions in the air; which was propoſed by Mr. *Whiſton*, and Mr. *Ditton*, maſter of the mathematical ſchool in *Chriſt's Hoſpital*. An account of this method may be ſeen in a pamphlet publiſhed by them, A. D. 1714. But this method, as obſerved by Sir *Iſaac Newton*, in a paper delivered by him to a Committee of the Houſe of Commons, "is rather for *keeping an account* of the *Longitude* at ſea, "than for *finding* it, if it ſhould be loſt; and that it is eaſier by it to "enable ſeamen to know their diſtance and bearing from the ſhore 40, 60, or 80 miles off, than to croſs the ſeas."

So that what whatever uſe it might be of near the ſhores, where indeed the *Longitude* is moſt wanted, yet, being impracticable in the open ſeas, it could never be rendered *univerſal*; and for that, among other reaſons, was never thought of afterwards.

The *third* method was ſaid to be by obſerving the *variation* of the Needle. But it is to be feared little advantage can be expected from thence. For that variation, as obſerved before, is not always the ſame at the ſame place; ſo that however it may ſerve, tollerably well, for a little while, yet, in a courſe of years, it will alter conſiderably. Whether that alteration be made uniformly or no, is not yet, for want of obſervation, ſufficiently aſcertained *. The neighbourhood of iron-mines, loadſtones, and even iron itſelf within the ſhip, are frequently found to diſturb the general rules, and to deceive the obſervers of that *variation*.

The *fourth* method for finding the Longitude of places, was ſaid to be Eclipſes of the Moon.

For the *immerſions* of the Moon into the Earth's ſhadow, its *neareſt diſtance* to the center of that ſhadow, and its *emerſions* out of the Earth's ſhadow, are all at *diſtinct* and known points of abſolute time. So that *where*, and *when*, they can be nicely obſerved, and the difference of the apparent time at every Meridian can be noted, the reſpective *Longitudes* of thoſe places may be thereby found in time; and by allowing 15° of the Equator to an hour, they may be found in *degrees* alſo.

* See Connoiſ. des Mouvem. Celeſt. for 1762.

EXAMPLE.

EXAMPLE.

Let the middle of a *lunar Eclipſe* be obſerved at a place called H, at 10 o'clock at night; but let the time at another called D be known by tables to be 11 o'clock, the *difference* is *one hour*, or 15°; therefore H lies 15° to the *weſtward* of D.

Had the time at D been 11 o'clock, and the time at another place, called I, been known to have been 12 o'clock, the place I would have lain 15° to the *eaſtward* of D.

Eclipſes of the Sun may, in the ſame manner, be of uſe in finding the Longitude of places.

For the *beginning*, *middle*, or *end* of a ſolar Eclipſe, being obſerved at H, or I, and it being known, by tables, in what manner the ſame time is reckoned at D, it will be known, likewiſe, by allowing 15° to an hour, how many degrees H or I is diſtant from D. If the time is earlier at H than at D, then H will lie to the *weſtward* of D; but if later, to the *eaſtward*. For places that lie to the Eaſt of others, come up to the Meridian, or under the Sun, by the rotation of the Earth on its own axis, ſooner than the others that lie weſtward.

The Eclipſes of *Jupiter*'s Satellites afford another method for finding the Longitude, exactly reſembling the firſt method by Eclipſes of the Moon; which makes any particular illuſtration of this method unneceſſary.

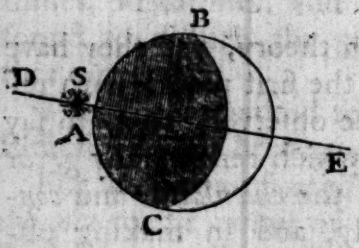
Though theſe methods are all of them true in theory, yet they have all of them their difficulties in practice: for, in the firſt place, with regard to Eclipſes of the Sun and Moon, it may be obſerved, that, to ſay nothing of the ſlowneſs of the Moon's motion, which renders any *great exactneſs* impoſſible, there is a great difficulty in the *calculation* and *conſtruction* of Eclipſes, thoſe of the Sun eſpecially, and in making obſervations on both. But beſides this, they happen ſo ſeldom, and are ſo frequently inviſible, through clouds and bad weather, when they do happen, that they are but of little uſe in Navigation, where the Longitude of places is wanted continually. The method, therefore, that will be of moſt uſe, muſt be that which will give the Longitude whenever it is wanted, or the *moſt frequently*, and with the *leaſt trouble* and intricacy of calculation; for more ſeamen have occaſion to know the Longitude of the place their ſhip is in, than are able to manage a calculation, eſpecially if it be of any length, or attended with any difficulty. Part of the inconvenience above-mentioned ſeems, at firſt ſight, to be remedied by

by the laſt of theſe methods, or by obſerving the Eclipſes of *Jupiter*'s Satellites; for the quickneſs of their motion, eſpecially that of the *innermoſt*, makes the moment of their *immerſion* into, or *emerſion* out of, *Jupiter*'s ſhadow, very diſtinct and nice; and their frequency, which is almoſt *one* for every day, renders them *fitter* for the conſtant uſes of *Navigation*; nor have we hitherto had any other method ſo uſeful at land as this.

And yet there are great difficulties attending this method, eſpecially at ſea. For the beſt tables of their motions, yet extant, are too imperfect to be intirely relied on in predicting the preciſe time when any of theſe Eclipſes will happen; and they require Teleſcopes of ſuch a length as, in the continual toſſings and agitations of ſhips at ſea, are not eaſily manageable. Theſe difficulties, added to the impoſſibility of ſeeing theſe Eclipſes for about *three* months in the year, when *Jupiter* is near the Sun, renders this method, at preſent, of ſo much leſſer uſe in Navigation, than at firſt ſight one would apprehend it to be.

The next method, which is by obſerving the motion of the Moon, her appulſe to, or occultation of, ſuch *fixed Stars* as lie along her courſe, is much of the ſame nature with *Eclipſes* of the *Sun*, as to this matter, as will appear by this ſhort

EXAMPLE.



Let ABC be the Moon, DE a portion of her Orbit, S a fixed Star. Let the time when the eaſtern limb of the Moon touches the fixed Star be known, by tables of the Moon's motion, to be in the Meridian for which thoſe tables are calculated, *e. g. Greenwich*, at 10^h 15′ P. M. but let the time, when this appulſe happens, be obſerved, at ſome other place, to be at 11^h 15′, the difference is juſt 1^h in time, which anſwers to 15° in the Equinoctial.

This laſt place, therefore, hath 15° of Longitude from the Meridian of *Greenwich*; and as the time is 1^h forwarder than as it is reckoned at *Greenwich*, it ſhews that the place lies to the *eaſtward* of *Greenwich*. Had the obſerved time been 9^h 15′, the difference would have been one hour, or 15 degrees, and the place would have lain ſo much to the *weſtward* of *Greenwich*.

This

This method, however promiſing, yet will not give the *Longitude* to ſuch exactneſs as is neceſſary; for, not to take notice of the *ſlowneſs* of the *Moon's motion*, the *places of ſome* of the *fixed Stars*, that lie in the *Moon's way*, are not known, with ſufficient exactneſs, as yet themſelves.

Beſides, there is a difficulty in managing Teleſcopes of ſufficient length at ſea, by reaſon of the ſhip's rolling and toſſing; to which muſt be added, the trouble of *calculating* and *conſtructing* ſuch *appulſes*, or *occultations*.

And laſtly, the theory of the *Moon's motion* itſelf, eſpecially in ſome poſitions of her, with reſpect to the Sun, is not hitherto exact enough for the purpoſe.

However, whenever this theory of her motion can be ſo far perfected that her place can be, with certainty, calculated nearer than to 2′ of a degree, this will be a very uſeful method in order to diſcover the Longitude at ſea.

As to the *ſixth* method, which is that by Clocks, or Watches, though the eaſieſt to underſtand and practiſe of all others, yet it hath been ſo long attempted at ſea in vain, that there ſeems to remain but little hopes of its future ſucceſs.

Watches are ſo influenced by heat and cold, moiſture and drought, and their ſmall ſprings, wheels, and pevets, are ſo incapable of that degree of exactneſs which is here required, that no body now pretends to depend upon theſe at all.

Clocks governed by long Pendulums, inſtead of ſprings, go much truer, and, could they be made in a proper manner, would ſhew the Longitude of the ſhip at any time. For being ſet true for the Meridian of the place from whence the ſhip ſet ſail, it would ſhew the time, under any other Meridian, as reckoned at the former place; and then the true time being found by the Sun, or Stars, in the place where the ſhip is, the difference between that time and the time ſhewn by the Clock, will be the *difference* of the *Meridians* in time; from whence the Longitude will be had in degrees, as before explained.

EXAMPLE.

Let a ſhip ſet ſail from the *Lizard*, and the Clock be adjuſted ſo as to ſhew the true time there, and let the ſhip ſail weſtward. Some days after this, let the time, by *obſervation*, be 10 o'clock at night, but, by the Clock, let it be 11; the difference is one hour, which, by what

hath

hath been already obſerved, gives 15° of Longitude. By which it appears that the ſhip is in 15° of Longitude Weſt from the *Lizard*.

But here it is to be obſerved, that it is not eaſy to make ſuch a movement as will, in all weathers and climates, go truly, eſpecially in ſome of the ſouthern ones, where the dews are ſo *great* as to ruſt the parts of it, and to *retard*, if not intirely *ſtop*, its motion.

Another inconveniency is, that in different Latitudes the hours ſhewn by the Clock will be different from thoſe ſhewn by it for the Latitude to which it is fitted. For it is a known property of all metals, that they *lengthen* by *heats*, and *contract* by *colds*. So that a Clock made at *London*, and made to ſhew the true time there, when carried under the Equator, will go too ſlow by two or three minutes; and the law of *retardation*, as we go *ſouthward*, is not very well known.

Notwithſtanding this, Mr. *Huygens*, in his excellent treatiſe called *Horologium Oſcillatorium* *, mentions two Clocks, that were formerly made by his directions, there laid down, which being carried to ſea in an *Engliſh* ſhip, in company with three other ſhips, very much aſſiſted the captain in judging of the place of his ſhip. For the captain reported, that when they had ſailed from the coaſt of *Guinea* to the Iſland of St. *Thomas*, under the Equinoctial Circle, and there ſet the Clocks to the Sun, they ſailed *weſtwardly* about 70 miles, and then directed their courſe toward the *African* ſhore; and when they continued on upon a courſe for about 2 or 300 miles, the captains of the other ſhips, fearing that they ſhould want water before they could arrive at the coaſt of *Africa*, were for going to get water at the *American* iſlands, called the *Caribbees*.

Upon this, a conſultation being held, the journals and reckonings of each ſhip were produced, all of whom differed from the captain's who had the Clocks on board; one 120 miles, another 100, and the third ſtill more. But the captain himſelf ſaid, he gathered from his Clocks, that they were not more than about 30 miles from one of the *African* iſlands, called *Del Fuego*, nigh to the coaſt of *Africa*, and might arrive at it the next day. And ordering them to direct their courſe accordingly, they ſaw the ſaid iſland the next day at noon, and a few hours afterwards arrived there.

Mr. *Huygens*, in the ſame book, ſays, that afterwards, by the command of *Lewis* XIV. the *French* and *Dutch* made various experiments with different events; which he attributed often more to the negligence

* Page 47.

and

and unskilfulness of the persons to whose care they were commited, than to any faults in the Clocks themselves.

But the most ingenious and best Clock that ever was, or perhaps can be made, for this purpose, is that of Mr. *Harrison*, in *Leather-lane*, *London*.

For the history of the several improvements made in this machine, from time to time, its exactness, and other interesting particulars relating to the success of it, see the *Connoissance des Mouvem. Celest.* for 1765.

And here, before we dismiss this subject, it may not be improper to add the following

P R O B L E M.

The day of the month being given, to find by the Globe what Stars lie *in*, or *near*, the Moon's way.

For a day before, and a day after, the given day, look in an Ephemeris for the Moon's place in the *Ecliptic*, and her *Latitude*; and in those points stick small black patches. Then laying a thread, or the Quadrant of Altitude, over those patches, it will *nearly* represent the Moon's way for that time, and consequently shew what Stars lie *in*, or *near*, it.

E X A M P L E.

I find by *White*'s Ephemeris for A. D. 1756, that the place of the *Moon* was, *September* the 14th, in *Gemini* 0° 1′, with *Latitude* 5° 15′ *South*.

The day before, or *September* the 13th, it was *Taurus* 17° 52′, with *Latitude* 5° 6′ *South*; and the day after, or *September* the 15th, her *Longitude* was *Gemini* 12° with *Latitude* 5° 10′ *South*; all which will be as in this short table.

Day	Moon's Long.	Moon's Lat.
13	*Taurus* 17° 52′	5° 06′
14	*Gemini* 0° 01′	5° 15′ S
15	*Gemini* 12° 00′	5° 10′

Then sticking small black patches, and laying a thread, or the Quadrant of Altitude, over them, we shall find that the Moon will pass over the Star called *Aldebaron*, or the *Bull's eye*.

And this brings us to the great ornament of his Age and Nation, and to whom Mathematics and Philoſophy are more indebted than to all that went before him; and that is,

SIR ISAAC NEWTON.

In his Philoſophy at laſt is compleated *Virgil*'s wiſh; as *that*, and *that* alone

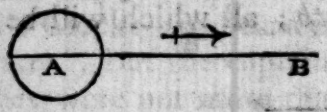
——— Cæliq; vias & ſidera monſtrat,
Defectus Solis varios, Lunæq; labores.
Unde tremor Terris: qua vi Maria alta tumeſcant
Obicibus ruptis, rurſuſq; in ſe ipſa reſidant.
Quid tantum Oceano properent ſe tingere ſoles
Hyberni, vel quæ tardis mora noctibus obſtet.

With what view he compoſed his *Principia* cannot be repreſented better than in his own words, in a letter to Dr. *Bentley*.

"When I wrote my Treatiſe (ſays he) about our Syſtem, I had an "eye upon ſuch principles as might work with conſidering men for the "belief of a Deity. And nothing can rejoice me more than to find it "uſeful for that purpoſe. But if I have done the public any ſervice "that way, it is due to nothing but *induſtry* and *patient thought*."

As the foundation of all his Philoſophy, he lays down three *rules*, or *laws*.

I. That all bodies continue in the ſame ſtate they are in, either of reſt, or of moving on uniformly in a ſtreight line, unleſs they are obliged to change their ſtate, by ſome external force or other, impreſſed upon them.

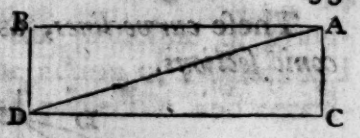


Thus if the body A be ſuppoſed to be at reſt, if no external force puts it into motion, it will always continue *at reſt*.

But if any impulſe be given it in the direction AB, unleſs ſome new force hinders or ſtops it, the body A will continue to move on uniformly, for ever, in the ſame direction AB.

II. That every change made in the motions of bodies is proportionable to the force impreſſed; and that this change is made along the right line continued in which the new force acts.

Thus



Thus let any body, as A, be carried by any force, causing it to describe the line AB in a given particle of time. At A let it receive a new impulse from a force, which, acting in the direction AC, would cause it to describe, in the same time, the line AC. Was the first force, acting along the strait line AB, to cease, the body A would continue its motion in the line AC, produced in *infinitum*.

But if the first force is not destroyed, when the body is at A, it will, by these joint forces, no longer describe the line AB, or AC, but the diagonal of the Parallelogram ABDC, that is, the right line AD.

This is called the *composition* of forces, which, in this case, are supposed to act *uniformly*.

This *composition of forces* Sir *Isaac Newton* makes great use of in explaining the *actions* of the Earth and *Sun* upon the Moon, as well as in other parts of his Philosophy.

III. That action and reaction are always equal, and contrary to each other; or that the actions of two bodies upon each other are always equal, and directed towards contrary parts.

Thus the *Magnet*, or *Loadstone*, attracts iron, and iron equally attracts the *Loadstone*; the Moon gravitates towards the Earth, and the Earth gravitates towards the Moon. And what is said of these two bodies, will equally hold good of any other two particles of matter. Upon this single principle, likewise, of *universal gravitation*, his whole System is built; for by this *gravitation*, joined with a *projectile force*, all the *Planets* and *Comets* are retained in their Orbits.

He doth not pretend to explain the nature of *gravitation*; it is sufficient to know that it acts by a certain law.

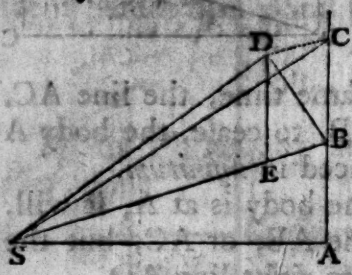
The law by which *gravitation* acts is this, that it *decreases* as the *squares* of the distances from the body towards which the *gravitation* is made increase.

Let A be the center of any body towards which another, B, may be supposed to *gravitate*; and from that center let there be taken the equal distances 1, 2, 3, 4, *&c.* The squares of these distances will be 1, 4, 9, 16, *&c.* The gravity, therefore, of the body towards A at 1 will be as 1; but the gravity of the same body at 2 will be only one-fourth, at 3 it will be one-ninth, and at 4 will be one-sixteenth of what it was at 1.



We may now see, in the next place, in what manner this *composition of forces*, and this *law of gravitation*, may be applied to motions in *curve lines*.

These *curve lines*, as far as we are concerned, are one or other of the *conic sections*.



Let us now suppose S to be any central body, and A to be the place of any other, gravitating towards it. Let A be carried, by a single impulse acting upon it at A, in such a manner, that it would describe the line AB in a given particle of time. In the same, or an equal particle of time, if nothing prevented, it would describe the line BC = AB.

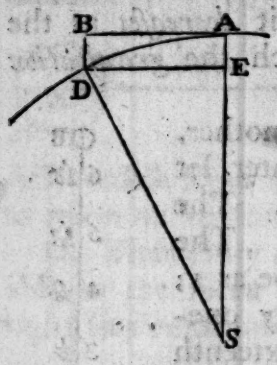
But at B let gravity act upon it in such a manner, that in the same time that it would describe the line BC, it would be carried downwards towards S, along the line BE.

From C draw CD parallel and equal to BE, and join SD. The point D will be the place of the body at the end of the second particle of time.

For because BC = AB, the Triangles ASB, BSC, will be equal. But because of the Parallels BES, DC, the Triangles BSC, BDS, will be equal, as standing upon the same base BS †. Therefore the Triangle BDS will be equal to the Triangle ASB, and the body will have described equal areas in equal times.

And this is the law, as was observed before, that was discovered by *Kepler*.

If the Times be diminished *in infinitum*, so will the Triangles BDS, and ASB, be diminished likewise; and the right lines AB, BD, will become portions of a Curve line. What species that Curve will be of, must be determined by the circumstances now to be taken notice of.



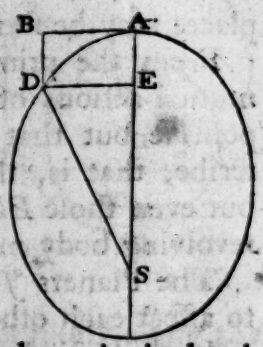
If the projectile force acting along the line AB be so adjusted to the *force of gravity*, or the *centripetal force*, acting in the direction AE, that when the body arrives at the point D, its distance DS from the central body S shall be equal to the distance AS, the Curve will be a *Circle*.

This is the only Curve that the ancients supposed the heavenly bodies, as the Sun, Moon, and Planets, described. For this was, in their opinion, the most perfect of Curves; and they could conceive nothing in the Heavens but what was perfect. If, however, the planetary

† Elem. lib. i. prop 37.

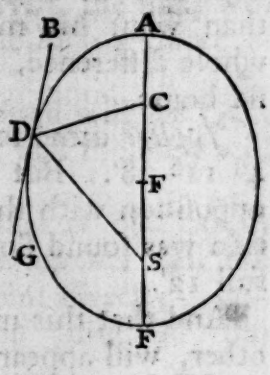
Orbits

Orbits were circular at firſt, it is certain, from the principle of gravitation, they could not always continue ſo. By the action of Planets and Comets upon each other, this adjuſtment of the projectile and centripetal forces will, in time, be deſtroyed.



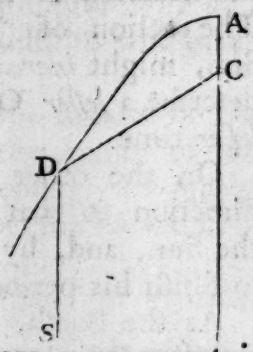
If then the *projectile force* acting along the line AB be ſo adjuſted to the *force of gravity*, or the *centripetal force*, acting in the direction AE, that when the body arrives arrives at D, its diſtance DS from the central body S ſhall be leſs than AS, and the Curve returns into itſelf, that Curve will be an *Ellipſis*.

And if the *projectile force* acting along the line AB acts perpendicularly to the line AE, or AS, the direction of the *centripetal force*, the line AE will be in the principal axis of that *Ellipſis*, and the point S will be one *focus* of it, ſometimes called the *lower focus*.



If from S, the place of the central body, to D, any point in the Ellipſis, there be drawn a line, as SD; and if at D there be drawn a line BDG touching the Curve in D, and making, with the line SD, the Angle GDS; and if towards A there be drawn from the ſame point D the line DC, cutting the axis ASE in C, and making the Angle BDC equal to the Angle GDS, then the point C will be the other *focus* of the *Ellipſis*.

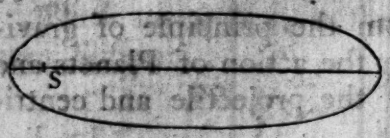
And if the line SC, the diſtance of the *foci*, be biſected in F, the point F will be the *center* of that *Ellipſis*, and FS, or FC, is called the *eccentricity*.



If the focus C be now ſuppoſed the *center* of force, or the point to which the body gravitates, and while that focus continues *fixed*, or the *ſame*, let the other focus be ſuppoſed to go off to an *infinite* diſtance, then the line DS, drawn from D to that other focus, will become parallel to the axis AC, and the *Ellipſis* will become a *Parabola*.

A *Parabola* is not a Curve returning into itſelf, and therefore doth not ſuit with any bodies that have a periodical return. Such *Ellipſes*, however, as are *very excentric*, will not ſenſibly differ, *near the Vertex*, from *Parabolas*.

This



This is the caſe of ſuch *Ellipſes* as are here repreſented, and are the Orbits of ſome Comets; and upon this ſuppoſition, Dr. *Halley* hath ſhewn a method by which their places may be found in ſuch *parabolic* Orbits.

From the principle of *univerſal gravitation*, it follows that, by the mutual actions of Planets and Comets upon each other, it is not impoſſible but that not only the ſpecies of the *Ellipſes* which they deſcribe, that is, their *eccentricities* and *periodical times* may be changed, but even thoſe *Ellipſes* may become *Parabolas*, ſtrictly ſo called, and the revolving body may never return again.

The Planets *Jupiter* and *Saturn*, being large bodies, are found ſenſibly to affect each other's motion.

In the period of *Saturn*, between the year 1668 and the year 1698, his motion was found ſhorter than what his mean motion gave it by ſix days and 20 hours. The period between 1689 and 1719 was longer than what his mean motion gave it by ſix days and 10 hours. The whole difference, therefore, between their periods is equal to 13 days ſix hours.

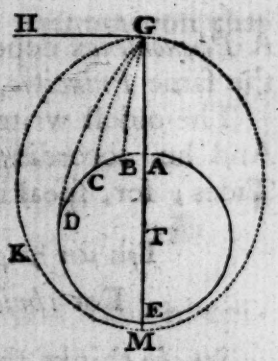
Jupiter came to an oppoſition with the Sun in the year 1667, *Auguſt* $4^d\ 11^h\ 58'$. But when, at the end of this period, he came again to an oppoſition with the Sun, in the year 1689, *Auguſt* $9^d\ 12^h\ 17'$, his motion was found ſlower than either in the *preceding* or *ſubſequent* period, by full $12'$.

And that this might ariſe from the actions of theſe Planets upon each other, will appear from hence, that in the year 1683, there was a conjunction of *Saturn* and *Jupiter*, in that part of their Orbits where, from the ſituation of their *apſids*, they approach the neareſt to each other. The action of *Jupiter*, therefore, conſpiring with the action of the Sun, might *increaſe* the centripetal force of *Saturn*, and, by making him deſcribe a *leſſer* Orbit, cauſe him to finiſh his periodical revolution in a *leſſer* time.

On the other hand, *Saturn*, by his action on *Jupiter*, in a contrary direction to that of the Sun, might *leſſen* his centripetal force towards the Sun, and, by making him deſcribe a *larger* Orbit, might cauſe him to finiſh his periodical revolution in a *longer* time.

As the Earth, and the reſt of the Planets are now acknowledged to deſcribe *Ellipſes* round the Sun, though not very *excentric*, ſome perſons find it difficult to comprehend in what manner a Planet, when it hath deſcended

deſcended from its *Aphelion* to its *Perihelion*, is thrown off, as it were, to its *Aphelion* again, and *vice verſa*.



This difficulty may be removed ſeveral ways; but as eaſy a method of doing it as any, perhaps, will be by conſidering in what manner falling bodies near the Earth may partake of the nature of Planets revolving about it.

Let the Circle ABCD repreſent the Earth, whoſe center is T. Let there be taken ſome point out of the ſurface of it, as G, and draw GH perpendicular to TG. It is evident that any body let fall from G, will, by its gravity, deſcend along the line GA, and meet with the Earth in the point A.

Beſides the force of *gravity*, by which the body falls freely along the line GA, let there now be impreſſed upon it an uniform *projectile* force, acting along, or in the direction of, the line GH. By the compoſition of theſe two forces, from what hath been already obſerved, the body will no longer, in its fall, deſcribe the right line GA, but ſuch a Curve as GB, meeting with the Earth in B.

If the *projectile* force be increaſed, the Curve deſcribed will be GC; and if it be increaſed yet more, the Curve will be GD, and the body will reach the Earth in D.

As the projectile force may be ſuppoſed to be increaſed at pleaſure, it is plain, it may be ſuppoſed to be increaſed in ſuch a manner that the body ſhall not touch the Earth till it reaches E, the point directly oppoſite to A, or even not at all, but come round to the point G, from whence it ſet out.

If the projectile force be ſo far increaſed that the points G and M ſhall be equally diſtant from the center of the Earth T, the Curve will be a Circle. In all other caſes, if the Curve *return* into itſelf, it will be an *Elliplis*.

It is to be remarked, that as gravity decreaſes as the ſquares of the diſtance increaſe, the farther the point G is from the center of the Earth, the leſs will be the *projectile* force required to change the *falling* body into a *revolving* one, that is, to make it partake of the nature of a Planet.

And this brings us, in the next place, to ſay ſomething, in general, on the

PHENOMENON

PHENOMENON OF TIDES.

A *Phenomenon* depending on the ſame *Luminaries*, and explicable only by the ſame *Principle*, whereby all matter is found to gravitate to matter.

The oldeſt writer among the *Greeks*, that is extant, at leaſt, is *Homer*. And he, according to *Strabo* *, was in ſome meaſure, acquainted with Tides; for, ſpeaking of the *Charybdis* †, he ſays,

Τρὶς μὲν γάρ τ' ἀνίησιν ἐπ' ἤματι τρὶς δ' ἀναροιβδεῖ.

For *thrice* each day it riſes, *thrice* retires.

Strabo thinks that the word τρὶς there muſt be a miſtake, and that it ſhould be δὶς *twice* only; and that this miſtake ariſes either from ſome corruption in *Homer*'s text, or from his being miſinformed himſelf.

But as there is little or no Tide at all in the *Mediterranean*, and *Charybdis* is only whirlpool in the Streights of *Sicily*, it may not be improbable that *Homer* accommodates to that place what he had heard *imperfectly* concerning ſome other. And a like inſtance of ſuch an accommodation in him we have ſeen long ago, when ſpeaking of the Sun's *amplitude* at *riſing* and *ſetting*.

The next Greek author that mentions any thing of Tides, is *Herodotus*; who ſpeaking of the *Red Sea*, or the *Arabian Gulph*, ſays ‡, that *there is a flux and reflux of water in it every day*. And *Diodorus Siculus* § deſcribes it to be ῥῶν δὲ πολὺν καὶ σφοδρόν, *a great and rapid Tide*. But all that theſe writers ſay of Tides is only as a *phenomenon*, without knowing, or even pretending to gueſs at, *any law* by which they were governed.

The firſt perſon that we meet with, at leaſt, among the *Greeks*, that knew any thing of *Tides*, as being in any ſort governed by the Moon, was *Pytheas* of *Marſeils*, who lived, as hath been ſaid, about the time of *Alexander the Great*. But when *Plutarch*, to whom we are indebted for this account, repreſents it as his opinion, that there was only *one* Tide in a *month*, this muſt be *Plutarch*'s own miſtake, who knew nothing of Tides himſelf. If *Pytheas* had been in this Iſland of *Great-Britain*, as from *Strabo* ‖ it appears he had been, he had ſeen and heard enough of Tides to know better.

* Page 9. † Odyſſ. xii. ver. 105. ‡ Page 92. Edit. Gronov.
§ Page 172. ‖ Page 163. Edit. Amſterd.

The

The Roman conqueſts having brought them acquainted with the *Ocean*, their Poets, from that time, frequently allude to Tides.

Horace, in his Epiſtle to *Iccius*, ſpeaks of Tides as a phenomenon that he had either ſeen or heard of.

Quæ Mare compeſcant cauſæ-------

And *Virgil* more fully in his ſecond *Georgic*,

------- *qua vi Maria alta tumeſcant*
Objicibus ruptis, rurſuſq; in ſe ipſa reſidant *.

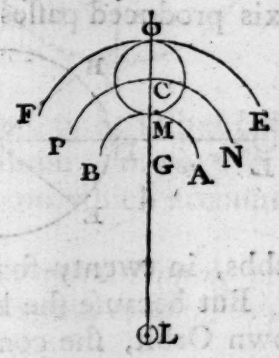
After this, *Lucan*, in his *Pharſalia*, enumerates the ſeveral received opinions of his time concerning Tides thus.

Ventus ab extremo Pelagus ſic axe volutet,
Deſtituatq; ferens: an Sidere mota ſecundo
Tethyos unda vagæ lunaribus æſtuet horis:
Flammiger an Titan ut alentes hauriat undas,
Erigat Oceanum, fluctuſq; ad Sidera tollat †.

But the firſt perſon that knew any thing of the *true cauſe* of Tides, as ariſing from the principle of gravitation, was the ſagacious *Kepler*. But Sir *Iſaac Newton* coming after him, ſo far improved upon the hints he had given, as to make the doctrine of Tides, in a manner, his own.

The principal agent in the cauſing of Tides is the Moon. And therefore we ſhall at firſt conſider only the action of that Luminary.

Let C be the center of the Earth, and L the Moon, and let G be the common center of gravity of the Earth and Moon.



Suppoſe, likewiſe, that the whole ſurface of the Earth is covered with water to a conſiderable depth.

Then ſince G is the common center of gravity of the Earth and Moon, they will jointly revolve about it; the point M deſcribing the Circle AMB, the point C the Circle NCP, and the point O the Circle EOF, and all in the ſame periodical time.

But the forces required to retain theſe points in their reſpective Circles, ought to be as GM, GC, GO, that is, *directly* as their diſtances from their common center of motion ‡.

* Ver. 475. † Lib. i. ver. 412. ‡ See Hygens's 1ſt Theorem of Mat.

But the force, by which theſe points are thus retained, is their gravity towards the Moon L. Conſequently the point O requiring the greateſt force, on account of its *greateſt* diſtance, will be attracted the *leaſt*.

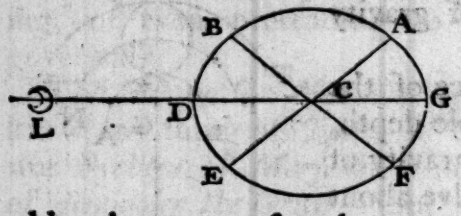
And the point M requiring the leaſt force, will, on account of its *nearneſs*, be attracted the *moſt*; that is, M will be attracted *too much*, and O *too little*.

The water at M, therefore, being attracted towards the center of the Earth C *leſs* than it ought to be, will loſe part of its weight, and, endeavouring to leave that center, will *aſcend*.

But the center C being more attracted towards the Moon L than the water at O, will, as it were, endeavour to *leave* it; and therefore the *tendency*, or *gravitation*, of the water at O towards the center at C, will be *leſs* than it ſhould be, and therefore will *aſcend*.

But the weight, or tendency, of the water at N and P, which may be ſaid to be in quadrature with the Moon L, will be augmented by the action of the Moon, in the ſame manner as the tendency of the Moon herſelf to the Earth at her quadratures, is augmented by the action of the Sun; ſo that the water at N and P will be heavier than an equal quantity of it at M and O. Conſequently, from the common principles of *Hydroſtatics*, the water at N and P will ſubſide, and force up the water at M and O, till the preſſure be every where equal, and the *equilibrium* be reſtored.

On this account, therefore, the Sea, thus ſuppoſed to cover the whole Earth, will become an *Oval*, or *oblong Spheroid*, as ABEG, whoſe longer axis produced paſſes through the Moon at L.



If, therefore, the Moon had no proper motion of her own in her Orbit, and only the apparent motion ariſing from the diurnal rotation of the Earth about its axis, this oval of waters would keep pace with her, cauſing *two* floods, and *two* ebbs, in twenty-four hours.

But becauſe ſhe hath a motion of her own, from Weſt to Eaſt, in her own Orbit, ſhe comes about three quarters of an hour later to the Meridian of any place than ſhe did the day before; and therefore makes *two* floods, and *two* ebbs, in about 25 hours.

The Moon hath hitherto been conſidered as the only agent concerned in raiſing the Tides. Her force, indeed, on account of her nearneſs to us, will be much the greateſt; but it muſt be remembered, that as the Moon thus raiſes and depreſſes the water, ſo the Sun doth the ſame,

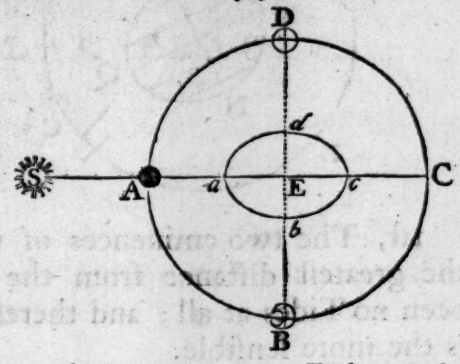
but

but in a much leſſer degree, on account of the ſmall proportion which the ſemidiameter of the Earth bears to the immenſe diſtance of the Sun.



For as the force of the Sun to diſturb the motion of the Moon round the Earth, is as the diſtance of the Moon from the Earth to the diſtance of the Sun from the Earth; ſo here, making ABCD the Earth, and S the Sun, and, inſtead of the Moon, taking any particle of water, as A, the force of the Sun to diſturb the motion of the particle A about the center of the Earth E, will be as AE, the diſtance of the particle A from the center of the Earth, to ES, the diſtance of the Sun S from the ſame center.

But AE, the diſtance of the particle A from the center of the Earth, *i. e.* the ſemidiameter of the Earth, is *very ſmall*, in proportion to ES, the diſtance of the Sun from the ſame center; and therefore the force of the Sun to diſturb the motion of the particle A, about the center of the Earth E, muſt be *very ſmall* too.



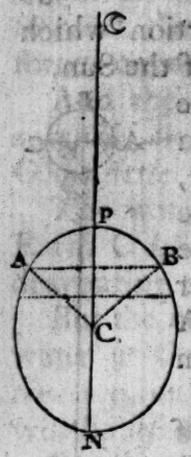
Let ABCD be the Orbit of the Moon, E the center of the Earth, *abcd* the ſpheroid of water, and S the Sun.

When the Moon is at A in *conjunction* with the Sun S, or at C in *oppoſition* to him, the Tides which each of them endeavours to raiſe are in the ſame place, and proceed from their united forces; which is the reaſon why they are ſo large at thoſe times.

Whereas, when the Moon is at B in her firſt quarter, or at D her laſt quarter, the Sun being in the Meridian, when the Moon is in the Horizon, *depreſſes* the water where the Moon raiſes it; on which account the Tides are then (*cæteris paribus*) the leaſt of all.

Theſe are called *Neap Tides*, q. d. *Nip Tides*; the word *Niipen*, or *Kniipen*, ſignifying, in the *Dutch* language, *arctare, ſtringere, comprimere*; and, in the *Anglo-Saxon*, *Naſte* ſignifies *inopia, want*.

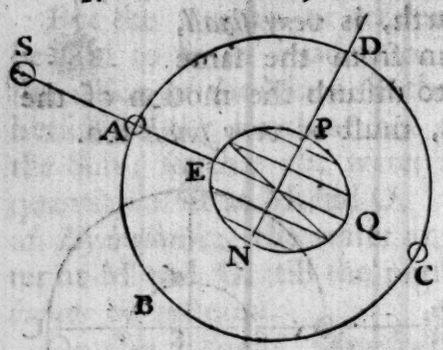
This is ſpoken only of Tides in general, and not as obſerved at any place in particular. For in ſome places it is ſaid to be *full ſea*, or high water, when the Moon is in the Horizon. Tides at particular places depend on circumſtances that will be taken notice of hereafter.



Let PN be the axis of the Earth; then if the Moon was fixed, without any motion, as here, in the Pole, the greateſt axis of the *ſpheroid* would coincide with the action of the Earth, and there would be no Tides at all.

The ſurface of the water, likewiſe, in the ſame Parallel of Latitude, as AB, will be every where equidiſtant from the center of the Earth, or ſpheroid, C. For it will be AC = CB; and therefore the depth of water, in that Parallel of Latitude, will be every where the ſame.

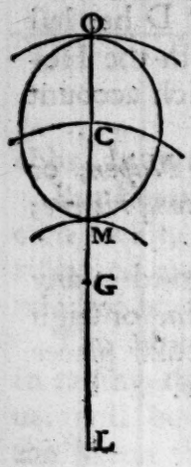
Let NP be now the axis of the Earth, EQ will be the Equator; which, being produced, let it paſs through the Sun S, and let ABCD be the Orbit of the Moon.



Then if the Moon be in conjunction with the Sun at A, or oppoſition to it at C, the axis of the watry ſpheroid will coincide with the Earth's Equator, as it did before with the axis of the Earth.

But when the Sun is in the Equator, it will be the Equinoxes; therefore at the full and new Moons that happen in, or neareſt to, the Equinoxes, the Tides will be the greateſt of all. For,

1ſt, The two eminences of water at E and Q, in the Equator, are at the greateſt diſtance from the Poles, where, as was ſaid, would have been no Tides at all; and therefore the difference between flood and ebb is the more ſenſible.

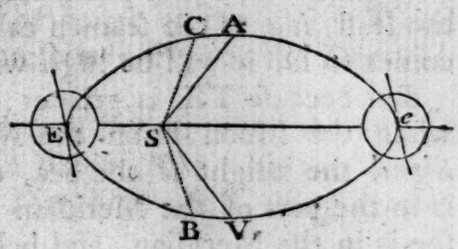


2dly, The equatorial diameter of the Earth produced paſſes through the Sun and Moon. But this diameter, as ſhewn before, is longer than all the others; and ſo there is a greater diſproportion between the diſtances OG, CG, MG, in the figure here, and OL, CL, ML, than at any other times.

3dly, The water now riſing higher in the open ſeas than at other times, ruſhes to the ſhores with greater violence, where, being ſtopped, it riſes higher ſtill.

For it riſes at the ſhores, not only in proportion to the height it riſes to in the open ſeas, but alſo according to the velocity with which it flows from thence againſt the ſhore.

Let



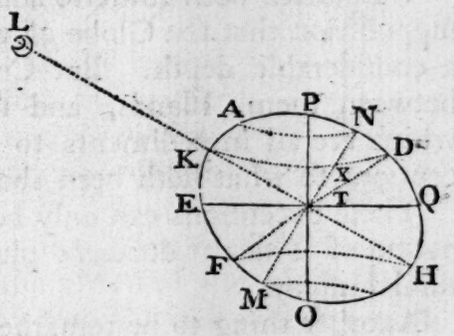
Let S be the Sun, E the Earth at the *Winter Solſtice*, and *e* the Earth at the *Summer Solſtice*, V the Earth at the *vernal Equinox*, and A the Earth at the *autumnal Equinox*.

Then ſince the Earth is nearer to the Sun at B, *before* it comes to the *vernal Equinox*, than at the Equinox itſelf, therefore it follows, that the Tides which happen in *February*, a little before the *vernal Equinox*, are the higheſt.

And for the like reaſon, becauſe the Earth is nearer the Sun at C, a little *after* it has *paſſed* the *autumnal Equinox*, than at A, the *autumnal Equinox* itſelf, therefore the Tides which happen in *October*, a little *after* the *autumnal Equinox*, are the higheſt.

Thus much being ſufficient to have ſaid of Tides in *general*, we may now add a word or two more particularly concerning

TIDES IN PARTICULAR PLACES.



Let AFD repreſent the Earth, whoſe center is T, and axis PO, the point P the North Pole, and O the South Pole, EQ the Equator, FH a a Parallel to it on the *South* ſide, and KD another Parallel to it on the *North* ſide.

Let the fluid ſurrounding the Earth form itſelf into an oblong Spheroid, whoſe longer axis HK, produced, paſſes through the Moon at L. The right lines TK, or TH, drawn from the center T, will repreſent the *greateſt height* of the water in thoſe places.

Then, ſuppoſing NM perpendicular to KH, TN, or TM, will denote the *leaſt height*, and will repreſent the height of the water in all parts of the Globe through which the Circle NM paſſes.

The right lines TE, TF, TH, TQ, TD, *&c.* will ſhew the height of the water in thoſe reſpective places E, F, H, Q, D, *&c.*

Let us now conſider ſome place in particular, which, by the diurnal motion of the Earth, deſcribes the Parallel KD. When that place is at K, the height of the water TK is the greateſt, *i. e.* it will be what the ſeamen call high water, and the Moon L will be in the Meridian. But

afterwards

afterwards when that place comes to X, the height of the water will be the leaſt, *i. e.* as the ſeamen call it, low water; and when the ſame place comes to D, it will be high water again.

But becauſe TK is greater than TD, therefore, in the preſent caſe, when the Moon is on the *North ſide* the Equator, or in the *northern Signs*, the height of the Sea, or Tide, will be greater when the Moon is in the part of the Meridian which is above the Horizon, than when ſhe is in the Meridian, and below it.

Hence it is that the Moon, when ſhe is in the *northern Signs*, makes the greateſt Tides on our ſide the Equator when ſhe is above the Earth.

Again; T H, on the South ſide the Equator, is longer than T F; and therefore, to a place that deſcribes the Parallel FH, the greateſt height of the water, when the Moon is in the *northern Signs*, is when ſhe is on that part of the Meridian that is below the Horizon of that place, and the leaſt Tides when ſhe is above the Horizon. For the like reaſon, when the Moon is in the *ſouthern Signs*, the greateſt Tides on the other ſide of the Equator will be when ſhe is below our Horizon, and the leaſt Tides when ſhe is above it.

What hath been hitherto ſaid of the Tides, muſt be underſtood upon ſuppoſiition that the Globe of the Earth is covered intirely with water to a conſiderable depth. But Continents which ſtop the Tide, Streights between them, Iſlands, and the ſhoalneſs of the Sea in ſome places, which are all impediments to the courſe of the water, cauſe many exceptions to what hath been above laid down.

Theſe exceptions can only be had from particular obſervations on the nature of Tides at different places; and therefore make a part of Natural Hiſtory.

Another thing to be remarked, under this article of Tides, conſidered with regard to particular places, is, that in theſe northern Latitudes, in the Summer time, when the Moon is in conjunction with the Sun, the Day-Tides are the higheſt, and the Night-Tides the loweſt.

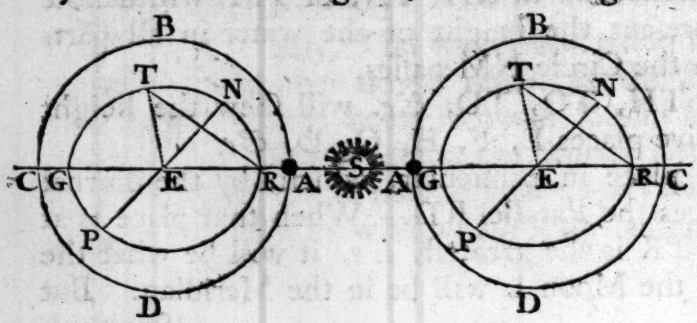


Fig. 1.

Fig. 2.

For if NP is the axis of the Earth, N the North Pole, P the South Pole, TR a Parallel of Latitude, GR the axis of the ſpheroid of water paſſing through the Moon (A) in conjunction with the Sun

(S)

(S) deſcribing her Orbit about the Earth ABCD. It is plain that TE, ER, as before, will repreſent the depths of water at the places T and R. But ER is greater than ET; and therefore in Fig. 1. the *Day-Tide* is higher than the *Night-Tide*.

But in Fig. 2. where the axis of the Earth *declines* from the Sun at the *Winter Solſtice*, when the Moon (A) is in conjunction with the Sun S, the *Night-Tides* will be *higher* than the *Day-Tides*; ER being greater than ET.

If the Moon be ſuppoſed at C, in *oppoſition* to the Sun S, or at the *full*, the caſe of the Tides will be juſt the ſame with the former.

In what hath been hitherto ſaid, it is obvious to remark, that the time of *high water* hath been ſuppoſed to be when the Moon is in the Meridian of any place.

But this doth not agree with phenomena; for *high water* is always an hour, or two, and, perhaps, more, after the Moon hath paſſed the Meridian.

For let ABCD be the Earth, and L the Moon. Then the water which is raiſed by the action of the Moon in the Meridian BD, by the motion of the Earth about its own axis, immediately recedes from the point B towards C.



But by the action of the Moon, the axis of the watry ſpheroid paſſes through the Moon. Therefore the water is continually agitated, as it were, by two contrary forces, one the *action* of the Moon, the other the *rotation* of the Earth about its own axis.

So that from A and C the water flows by the action of the Moon towards D and B; but the water raiſed by the action of the Moon at B, is carried, by the *rotation* of the Earth, towards C; and meeting with the water ſwelling from C towards B in ſome intermediate point, as E, cauſes the higheſt accumulation of the waters, or *high water* at the point E; that is, two or three hours *after* the Moon hath paſſed the Meridian of the place.

From what hath been obſerved before of the Tides, it ſhould ſeem as if they were always the *higheſt* at the time of the *new* and *full Moons*. But this doth not agree with phenomena; for the *higheſt* Tides are not on the day of the *new* and *full Moons*, but two or three days afterward.

For the action of the Luminaries upon the water, on the day of the *new* and *full Moon*, being *ſuperadded* to their actions on it the precedent days, makes the action greater than had it been the ſingle action of that day.

day. The action of the next day, being added to all theſe former actions, increaſes the force, in the ſame manner as the *hotteſt* weather is obſerved to be, not *at* the time of the *Solſtice* in *June*, but ſome time *after*.

As a farther illuſtration of what hath been offered on the doctrine of Tides, it will not be amiſs to take notice of a piece of Hiſtory preſerved by *Diodorus Siculus* * and *Agatharchides* †. This laſt author wrote Lectures, or Inſtitutes, as it ſeems, for the uſe of *Ptolemy Alexander* king of *Egypt*, about the year before Chriſt 114. They appear, by the ſhort ſpecimen that remains of them, to have contained many curious particulars in Natural Hiſtory and Geography. The following is pertinent to the ſubject in hand.

This author, therefore, ſpeaking of the *Ichthyophagi*, a people bordering on the *Red Sea*, or *Arabian Gulph*, ſays, that the Tide brought great quantities of fiſh along with it, ὃ ποιεῖ δὶς ἑκάστης ἡμέρας, πρὸς ὥραν ἐννάτην τε καὶ τρίτην, *which it doth twice every day, once at the third hour, and again at the ninth.* But in whatever ſenſe we take the word Πλημμυρὶς, whether for the *coming in* of the Tide, or for the time of *high water*, and however we underſtand the *third* and *ninth* hour, the thing *cannot be true* as it is here repreſented.

The doctrine of Tides, as obſerved before, was very little underſtood by the ancients; and this is the leſs ſurpriſing, as there is little, if any, Tide in the *Mediterranean*, with which they were beſt acquainted. It ſeems not improbable that this account is formed from the repreſentation of different people. Some of theſe might have been upon the ſhore of the *Ichthyophagi* when it happened to have been *flood*, or *high water*, at the third hour, and others when it was ſo at the ninth hour. *Agatharchides*, therefore, meeting with this account from both, might conclude that it was a *conſtant* phenomenon every day at thoſe two hours. But as the time of flood is now known to vary every day, if it was Tide of flood to-day at any particular place at the third hour, it would be later the next day, and later than that the day following, and ſo on.

The ſame obſervation, likewiſe, holds good with reſpect to the time of *high water*, or *full ſea*, which depends on the time of flood.

As we know neither the ſituation of theſe *Ichthyophagi* exact enough, nor yet the *time* of the *year*, nor the *Moon's age*, our reaſonings here muſt be very imperfect. For Tides not only depend, for their quantity, on the actions of the Sun and Moon, as they conſpire, or not, but happen

* Page 174. † The fragment containing this is in Hudſon's Geog. Min. vol. i. p. 28.

ſooner,

ſooner, or later, according as the Moon comes to the Meridian of the place, which, therefore, will differ with the Longitude of the place.

From the deſcription given by *Agatharchides*, it ſeems as if theſe *Ichthyophagi* were to be placed towards the *top*, or *North end*, of the *Arabian Gulph*. This Gulph is called by the Arabian geographers *Bahar Al Kolzum*, or the *Sea of Kolzum*, from a ſmall town of that name, at the extremity of it, and placed by *Abulfeda* in Latitude 28° 20′ North.

As the time of the year is not ſpecified, we are at liberty to aſſume one at pleaſure, which, therefore, ſuppoſe to be the VERNAL EQUINOX.

And as the time given above was the *third* hour, that would be, according to our way of reckoning now, about *nine* o'clock in the *morning*; as the *ninth* hour, at the ſame ſeaſon of the year, would be about *three* o'clock in the *afternoon*.

This ſeaſon of the year is made choice of, in order to avoid multiplying difficulties without any neceſſity, and for the farther uſe that will ſoon be made of it. For the hours now, being equinoctial hours, will want no reduction; and when they do ſo, the manner of reducing them may be ſeen before.

If, therefore, by Πλημμυρὶς we underſtand the time of flood, the Tide would come to the *Ichthyophagi*, at the *Vernal Equinox*, at nine o'clock in the morning, ſuppoſing the obſervation to have been made there, and at three o'clock in the afternoon.

The time of the day depends upon the apparent motion of the Sun; but the time of flood, at any place, is regulated by the Moon's diſtance from the Sun, or the time of her coming to the Meridian, as obſerved before. This diſtance of the Moon from the Sun is called frequently the *Moon's age*; and, therefore, as this is not given, we may aſſume it at pleaſure, and ſuppoſe her to be at the *conjunction*. Since the Sun, therefore, was ſuppoſed to be at *Aries*, the Moon muſt have been there too. And from thence we ſhall have the following

PROBLEM.

The Latitude of the place, and the place of the Sun and Moon, and the hour of the day when it is *flood*, or *high water*, being given, to find the Moon's *azimuth* at time.

Rectify the Globe for the Latitude of the place. Bring the Sun's place up to the braſs Meridian, and ſet the hour-index to twelve at noon. Find the Moon's Longitude and Latitude, or Declination, by an Ephe-

meris, and ſtick a ſmall black patch there, as before. Turn the Globe about, till the hour-index points to the given hour. Fix the Quadrant of Altitude in the Zenith, and lay it over the Moon's place. Then will the Arch in the Horizon, intercepted between the Meridian and the place where it is cut by the Quadrant of Altitude, ſhew the Moon's *azimuth* at that time.

EXAMPLE.

Let the Latitude of *London*, at St. *Paul*'s, be - -		51° 30″
Let the Sun's place be *March* 20, 1765 - -	*Aries*	00 00
Let the Moon's place for the ſame time be -	*Piſces*	17 28
And her Latitude North - - - -		00 00
And let the time of high water be that day, at *London-Bridge*, at - - - - -		01h 36′

Rectify the Globe accordingly, and turn it about its axis, till the hour-index points to 1h 36′. Then fix the Quadrant of Altitude in the Zenith, and lay it over the Moon's place; it will cut the Horizon in 38 degrees from the braſs Meridian, which will be the Moon's azimuth required.

In the ſame manner rectify the Globe for the Latitude of *Kolzum*, or 28° 20′ North.

Let the place of the Sun be - - -	*Aries*	0° 00′
Let the Moon's place be the ſame, and without any Latitude.		
Let the time of high water at *Kolzum* be *nine* o'clock in the morning.		

Fix the Quadrant of Altitude in the Zenith, and lay it over the Moon's place; it will cut the Horizon in 65°½ from the braſs Meridian, and that will give the Moon's azimuth required.

It would be ſame, nearly, ſuppoſing the time given to be three o'clock in the afternoon.

Let the time given be now ſuppoſed four o'clock in the morning, the place of the Sun the beginning of *Aries*, as before; but let the Moon be a little paſt the *oppoſition*, ſuppoſe in the beginning of *Scorpio*, without any Latitude. Let the Latitude of the place continue the ſame. Then the Moon's azimuth will be found about 43 degrees.

Hence, likewiſe, as the converſe of the former, we may add the following

PROBLEM.

PROBLEM.

The Latitude of the place, and the place of the Sun and Moon, together with the Moon's azimuth when it is *flood*, or *high water*, there, being given, to find the hour.

Rectify the Globe for the Latitude of the place, the Zenith, and the Sun's place, and set the hour-index to twelve at noon. Find the Moon's place by an Ephemeris, as before, and mark it with a small black patch. Set the Quadrant of Altitude to the given Azimuth, and turn the Globe about its axis, till the Moon's place comes up to it. Then will the hour-index shew the hour.

EXAMPLE.

Let the Latitude of *Kolzum* be, as before, 28° 20′; and let the Moon's azimuth be 47 degrees.

Let the Sun's place be - - -	*Aries*	0°	00′
The Moon's place be - - -	*Scorpio*	0°	00′
And her Latitude North - - -		3°	30′

Set the Quadrant of Altitude to 47 degrees, and the hour-index will point to *four* o'clock in the morning.

From the doctrine of Tides, above laid laid down, it appears, that at the same place there must be the difference of 12 hours, at least, between two *successive* full Seas the same day; and therefore if it was *high water* to the *Ichthyophagi*, or at *Kolzum*, at the third hour, or at nine o'clock in the *morning*, it could not be *high water*, or full Sea, there again the same day at the ninth hour, or at three o'clock in the *afternoon*, yet it follows that if it was *high water* there at three o'clock in the *afternoon*, it would be *high water* there again at about 3½ o'clock the next *morning*.

I have taken the more notice of this passage of *Agatharchides*, because it helps to illustrate a very singular point of ancient History. For it was about the *full Moon*, and the *vernal Equinox*, when the *Israelites* crossed the upper part of this *Gulph* *. The Tides are then the *highest*, and the ebbs the *lowest*. By the especial interposition of Providence, the ebb, at that time, was extraordinary, and unusual, by means of a strong *East* or *North-East* wind †. And what influence highwinds have in accelerating or retarding of Tides, is well known.

* Exod. xiv. † Ver. 21.

If then it is high water at *Kolzum* at 3½ o'clock in the morning, about the *vernal Equinox*, it muſt have been *tide of flood*, 10 or 12 miles below, much earlier than that.

But as the full Moon that year might not have been preciſely at the *vernal Equinox*, and the *Iſraelites* did not croſs over the Gulph at the *full Moon*, but a day or two after, the time of *high water*, and conſequently of *flood*, would be an hour later, or about day-break, *i.e.* between four and five in the morning. And accordingly we are told, that *the Sea returned to its ſtrength when the morning appeared, and the Egyptians fled againſt it* ‡.

That there was ſome tradition among the borderers on the *Arabian Gulph*, of this *extraordinary ebb*, appears from a remarkable paſſage in *Diodorus Siculus* §. "Among the *Ichthyophagi* bordering on theſe "places (ſays he) there is a tradition handed down from their anceſtors, "and ſtill preſerved, that upon a great receſs of the Tide, all that part "of the Gulph that appears green to the eye, became dry, the Sea re-"tiring backwards. But that when the bottom of the Sea had become "dry Land, a very violent return of the Tide reſtored the channel to its "former condition."

In the remarks made above on the paſſage from *Agatharchides*, we were obliged, on account of the imperfect manner in which the obſervation was delivered, to form ſeveral ſuppoſitions; it may not be improper now to introduce the following

PROBLEM.

The Latitude of the place being given, likewiſe the day of the month, and the Moon's Latitude, with her place in the Ecliptic, to find the time of her riſing, ſouthing, and ſetting.

Rectify the Globe for the Latitude of the place. The day of the month being given, the Sun's place will be given on the wooden Horizon. Bring the Sun's place to the braſs Meridian, and ſet the hour-index to 12 at noon.

Find the Moon's place by an Ephemeris, and ſtick a ſmall black patch there, as before. Bring the Moon's place up to the braſs Meridian; then will the hour-index ſhew the time of the Moon's ſouthing. Bring the moon's place to the edge of the eaſtern Horizon; then will the hour-index ſhew the time of the Moon's riſing. And if it be

‡ Exod. xiv. 27. § Page 174.

brought

brought to the edge of the weſtern Horizon, the ſame index will ſhew the time of the Moon's ſetting.

EXAMPLE.

Let the Latitude of the place be that of *Kolzum*, 28° 20′. Let the Sun's place be *Aries* 0; and the Moon's place be, as before, *Scorpio* 0, with Latitude North 3° 30′. There ſtick a black patch. Bring up the Sun's place to the Meridian, and fix the hour-index to 12 at noon. Turn the Globe about its axis, till the Moon comes under the braſs Meridian; then will the hour-index point to two o'clock in the morning, the time of the Moon's ſouthing. Bring the black patch to the edge of the eaſtern Horizon, and the hour-index will ſhew the time of the Moon's *riſing* at 15′ paſt eight in the evening. And if the ſame patch is brought down to the edge of the weſtern Horizon, it will ſhew the time of the Moon's ſetting at 45′ paſt ſeven next morning.

PROBLEM.

The Latitude of the place being given, likewiſe the Moon's Latitude, and her place in the Ecliptic, to find the time after ſouthing when ſhe will be in a given Azimuth.

Rectify the Globe for the Latitude of the place. Find the places of the Sun and Moon, as before, and the time of the Moon's ſouthing, as in the laſt Problem, which note. Fix the Quadrant of Altitude in the Zenith of the place, and turn it till it cuts the wooden Horizon in the given Azimuth. Turn the Globe about its axis, till the Moon's place comes to the Quadrant of Altitude. Then the hour-index will ſhew the hour. And the difference between this and the time before found, will ſhew how long it will be after her ſouthing before the Moon will be in the Azimuth given.

EXAMPLE.

Let every thing continue as before, and let the Moon's given Azimuth be 40 degrees. Fix the Quadrant of Altitude in the Zenith, and turn it till it cuts in the Horizon 40 degrees. Turn the Globe till the black patch comes to the edge of the Quadrant of Altitude; then will the hour-index point to 45′ paſt three o'clock in the morning, the time ſought; that is, 1 hour 45 minutes after ſouthing.

PROBLEM.

PROBLEM.

The place of the Moon in the Ecliptic, and her Latitude, being given, to find all thoſe places on the Earth to which ſhe will be nearly vertical that day.

Find the Moon's place in the Ecliptic by an Ephemeris, and apply one end of the Quadrant of Altitude to the Pole of the Ecliptic, and the other end to the Moon's place. On the Quadrant of Altitude mark the Moon's Latitude, and there ſtick a ſmall black patch. Bring that patch up to the braſs Meridian, and that will ſhew the Moon's declination.

Mark that point on the Meridian of the Terreſtrial Globe, and holding there a black lead Pencil, turn the Globe about its axis; the Pencil will deſcribe, on the Earth's ſurface, that Parallel to which the Moon will be nearly vertical that day.

EXAMPLE.

Let the Moon's place be, as before, - *Scorpio* 0° 0′
And her Latitude - - - - - - 3° 30′ *North*

There ſtick a black patch, and bringing it up to the braſs Meridian, her declination will be found about 7 degrees *South*.

Then holding a black lead Pencil at 8 degrees of *South* Latitude on the Meridian of the Terreſtrial Globe; and turning it about on its axis, it will deſcribe all thoſe places, *nearly*, that will have the Moon in their Vertex that day.

PROBLEM.

The Longitude and Latitude of the Moon being given, with the day of the month, and hour of the day or night, to find by the Globe all thoſe places where the Moon will be *riſing*, *ſetting*, or on the *Meridian*.

Find the Sun's place, and bringing it up to the braſs Meridian, ſet the hour-index to 12 at noon. Find the Moon's place, in *Longitude* and *Latitude*, by an Ephemeris, and mark it, as before. Turn the Globe about its axis, till the Moon's place comes up to the braſs Meridian; the hour-index will ſhew how long *before*, or *after* the Sun, the Moon comes to the Meridian.

EXAMPLE.

EXAMPLE.

Let the given day of the month be *June* 21, 1765.

Let the Sun's place be	*Cancer*	0°	0′
The Moon's place be	*Leo*	3°	45′
And her Latitude North		0°	0′

On the Celeſtial Globe find the Moon's place in Longitude and Latitude, and mark it with a black patch. Bring the Sun's place (*Cancer* 0° 0′) to the braſs Meridian, and ſet the hour-index to 12. Turn the Globe about its axis, till the Moon's place, marked with the patch, comes up to the braſs Meridian. The hour-index will point to 2^h 30′ the difference in right aſcenſion between the Sun and the Moon in time, or how long the Sun comes to the Meridian before the Moon.

Bring the patch marking the Moon's place up to the braſs Meridian, and it will ſhew the Moon's declination 20° 00′ North.

Bring the place for which the hour is given to the Meridian, and ſet the index to the given hour. Then turn the Globe about its axis, till the index points to 12 o'clock; then all thoſe places that lie under the braſs Meridian will have the Sun in the Meridian.

EXAMPLE.

Let the given place be *London*, and the time nine o'clock in the evening. Bring up *London* to the Meridian of the Terreſtrial Globe, and ſet the hour-index to nine o'clock. Turn the Globe, till the index points to 12 at noon. Then all thoſe places that lie under the braſs Meridian will have the Sun in their Meridian; theſe, in the preſent example, will be places in the great *Pacific Ocean*.

Say 1^h : 15° :: the number of hours between the Sun and the Moon's coming to the Meridian, to the correſponding number of degrees. Turn the Globe about its axis, till the number of degrees paſs under the braſs Meridian; then all thoſe places that lie under the braſs Meridian will have the Moon in their Meridian.

Or turn the Globe about its axis, till the hour-index points to the difference of right aſcenſion between the Sun and Moon in time, found before; and then all thoſe places that lie under the braſs Meridian will have the Moon in their Meridian; and the place whoſe Latitude is

equal

equal to the Moon's declination, found before, will have the Moon in its Vertex.

EXAMPLE.

The place of the Moon was found before in conſequence of the Sun, and the difference of right aſcenſion 2^h 30′. Turn the Globe weſtward, till the hour-index points to this difference, that is, at 9½; then, in this Example, all thoſe places in the *Pacific Sea*, that lie under the braſs Meridian, will have the Moon in the Meridian; and that point which lies under 20° 00′ North, will have the Moon in the Vertex.

If the difference of right aſcenſion had been ſeven hours, the Moon would be vertical to a place beween the Iſland *Formoſa* and the *Manila*.

Keep the Globe from turning about its axis, and raiſe the Pole to 20° 00′. Then drawing a line along the eaſtern ſide of the Horizon, it will paſs over all thoſe places where the Moon will be *ſetting*, as part of *California*, and *Button's Bay*; and drawing a line along the weſtern ſide of the Horizon, it will paſs over all thoſe places where the Moon will be *riſing*, as part of *Madagaſcar*, and the coaſt of *Africa* bordering on the *Mediterranean*, *Sicily*, *France*, and the North of *Scotland*.

At ſome places the time of high water, at the *full* and *change* of the Moon is known by obſervation. Thus, *e. g.* at *London Bridge*, on the day of the *full* and *change*, it is high water at three o'clock in the afternoon, when the Moon's azimuth is in the firſt caſe N. E. and in the latter S. W. From whence ariſes the following

PROBLEM.

The time of high water at any place, at the *full* and *change* of the Moon, being given, likewiſe having the day of the month, and the Moon's age, to find the time of *high water* for that day.

Having the day of the month, find on the wooden Horizon the Sun's place in the Ecliptic. Bring it up to the braſs Meridian, and fix the hour-index to 12 at noon.

The Moon's age being given, find her place on the Globe, and there ſtick a black patch. Turn the Globe, till it comes up under the braſs Meridian, and the hour-index will ſhew the time of the Moon's *ſouthing*.

Add

Add that time to the time of high water at the *full* and *change*, already known by obſervation, and that will give the time of high water at the given place that day.

EXAMPLE.

Let the given day of the month be *June* the 7th, A. D. 1733, that is ſeven days after the change of the Moon.

The Sun's place that day was - - -	*Gemini*	27° 00′
The Moon's place that day - - -	*Virgo*	18° 41′
Her Latitude South - - - - - -		4° 59′

Bring the Sun's place up to the braſs Meridian, and ſet the Hour-index to twelve o'clock. Stick a black patch at the Moon's place *Virgo* 18° 41′, with Latitude South 4° 59′. Bring it up to the braſs Meridian, and it will be found, that

At *London* the Moon was South that day at - -	5h 30′
Time of high water at *London Bridge*, at the full and change of the Moon, about - - - - - -	3h 00′
Time of high water there *June* the 7th at - - -	8h 30′

If it happens that this ſum exceeds 12 hours, then 12 hours muſt be ſubtracted from the ſaid ſum, and the remainder will give the time of high water the next morning. Thus, *July* 17, 1765,

The Moon was South that day at - - - -	11h 34′
Time of high water at the full and change - -	3h 00′
Sum - - - -	14h 34′
Subtract - - - -	12h 00′
Time of high water next morning *July* 18 - -	2h 34′

For places where the Sea ebbs and flows regularly, that is, in 12 hours 48 minutes, we may add the following

PROBLEM.

The day of the Moon's age, and the hour when it is high water, being given, to find the time of high water there at the *full* and *change* of the Moon.

This Problem doth not properly belong to the Globe; however, as it relates to the ſubject in hand, is not improper for this place.

By the mean motion of the Moon from the Sun, the time of high water falls out later every day by 48′, 8. Therefore, ſince great accuracy cannot be expected here, multiply the given day of the Moon's age by 48′, 8, and ſubtract it from the time of high water at the full and change of the Moon.

Thus, *e. g.* let the time of high water be 4^h 55′ on the 6th day of the Moon's age. But 48′, 8, multiplied by 6, will give 292′, 8 = 4^h 52′ 8, or, adding 1 for the decimal 8, 4^h 53′. This, ſubtracted from 4^h 55′, leaves only 2′; which ſhews that it is high water there, on the day of the new and full Moon, much about 12 o'clock at noon.

With Tides in the Ocean are intimately connected

TIDES IN THE ATMOSPHERE.

For what hath been hitherto ſaid of the actions of the Sun and Moon, and their forces in raiſing the waters on our Earth, may be equally applied to their actions on our Atmoſphere, and that current of air uſually ſtiled WINDS, or, if more violent and impetuous, STORMS.

For the air that ſurrounds us being a fluid, and ſo much lighter than water, muſt (eſpecially having nothing to check it, as ſhores do the Sea) more eaſily accommodate itſelf to the *ſpheroidal* figure above explained.

The Moon, being ſo much nearer to the Earth than the Sun, muſt have greater force than the Sun in raiſing Tides in the Atmoſphere, as well as in the Ocean. However, as in the caſe of the waters, above explained, the whole effect muſt be aſcribed to the joint actions of both Luminaries, which, therefore, will be *greateſt* when they conſpire together, and *leaſt* when the action of one checks, or, in part, counterbalances the action of the other.

The tranſverſe axis of the *ſpheroid* of the Atmoſphere will be longeſt when it paſſes through the centers of the Sun and Moon at, or near, the Equator; and therefore the greateſt ſtorms will be *about* the times of the two Equinoxes. For, as obſerved before, the higheſt Tides in the waters are not *preciſely* at the Equinoxes, but a little *before* the *vernal Equinox*, and a little *after* the *autumnal*.

Therefore, the Earth being nearer the Sun a little before the vernal Equinox than at it, the higheſt Tides in the Atmoſphere will be, *ceteris paribus*, *before* the *vernal* Equinox, and a little *after* the *autumnal*.

Hence ſome of the moſt remarkable ſtorms have been obſerved to have happened in *February* and *November*.

The

The ſtorm *November* 26, A. D. 1703, a little before midnight, was very remarkable, and attended with extraordinary effects.**

The ſame forces that thus affect the Atmoſphere, muſt, in a proportionable degree too, affect the human body, and particularly its fluids.

Hiſtory, eſpecially that of *Medicine*, affords many and remarkable inſtances of this.

The influence of Moon in *Epilepſies* was taken notice of by *Galen* † about one hundred years after Chriſt, in the reign of the emperor *Trajan*.

And before his time the perſons ſubject to this diſorder are called, by the writers of the New Teſtament, Σεληνιαζόμενοι ‡.

It is reported of the famous Lord Chancellor *Bacon*, that at every Eclipſe of the Moon he conſtantly fell into a *fainting fit*, from which he recovered only as that Luminary recovered its light §.

The ſtorm in which *Oliver Cromwell*, the Protector, died, *September* the 3d, 1658, was very remarkable, and gave occaſion to the Poets of that time to make reflections upon it, different, as their ſyſtems of politicks were different.

But without entering at all into ſecret cauſes, his diſorder was a feaver, attended with anguiſh of mind, ariſing from the ill poſture of his affairs at that time, eſpecially his domeſtic ones.

And it deſerves remarking, ſays a very great phyſician, " magni illius " viri morbum ex illorum genere fuiſſe, quos *vim lunarem* maxime ſen- " tire oſtendimus.*"

But, perhaps, as extraordinary and uncommon an effect of this *lunar* force as any, is what the ſame learned writer quotes from *Kerkringius*, who ſays, " that he knew a young gentlewoman, who at the time of " the *full moon* was plump and very handſome, but in the decreaſe of the " planet, ſo wan and ill-favoured, that ſhe was aſhamed to go abroad, " till the return of the *new moon* gave fullneſs to her face, and attraction " to her charms.**"

Every one knows how great a ſhare the moon hath in forwarding thoſe evacuations of the female ſex, which have their name from the conſtant regularity they keep in their returns.

In countries neareſt the Equator, as it hath been obſerved, the *lunar* action in raiſing the tide is the ſtrongeſt. No wonder, therefore, that theſe

** See Philoſ. Tranſ. No. 289. † De Dieb. Criticis l. 3. ‡ Matt. xvii. ver. 15. and other places. § See his life by *Rawley*. * Mead de Imp. Solis & Lun. p. 108.
** Mead ut ſup. pag. 58.

monthly ſecretions, are in thoſe countries, in much greater quantities than in thoſe that lie nearer the Poles, where the *lunar force* is weaker.

This *Hippocrates* * takes notice of, and aſſigns as one reaſon why the Scythian women were not very fruitful.

On the other hand, that ſuch plentiful ſecretions as are found in the warmer climates ſhould be attended with great *weakneſs* and laſſitude, is not ſurpriſing.

This appears in the caſe of *Rachel*, who excuſes herſelf from riſing up to her father †, "becauſe (ſays ſhe) the *cuſtom of women* is upon me."

Having thus far conſidered the effects of the Moon's action on the waters, air, and human bodies, we may next proceed to take notice of her own motion, and how it is affected by the ſame principle of univerſal gravitation. That is, in other words, to ſpeak of what are called

THE MOON'S IRREGULARITIES.

There is nothing that ſhews better the excellency of the NEWTONIAN phiſoſophy, or more clearly demonſtrates the truth of its principles, than its ſo eaſily, and clearly, accounting for thoſe many *irregularities* of motion, to which all *ſecondary planets*, and the *moon* in particular, are ſubject.

Though theſe are called *irregularities*, yet they are not to be apprehended as *random* or *fortuitous* ones, but ſuch as are *regular* under the like circumſtances, and ſubject to *numbers* and *calculation*.

For it was by obſerving the *period* of theſe lunar *inequalities*, that, as we ſaw before, Dr. *Halley* was enabled to foretell an eclipſe of the Sun, with an exactneſs little inferior to the obſervation itſelf.

It hath been ſeen before that *Gravitation* is a principle belonging to all *Matter*, as far as we are acquainted with it. And that bodies, deſcribing orbits about another placed in the center of their motion, by a *centripetal* and *projectile* force, deſcribe *equal areas in equal times*, is now very well known.

As this is the law by which the *primary Planets* regulate their motions about the *Sun*, ſo likewiſe, was there *no Sun*, by the ſame law would the *Moon* regulate her motion about the *Earth*.

This tendency of the *Moon* towards the *Sun* then, is the cauſe of thoſe *inequalities* in her motion, which are ſtiled her

IRREGULARITIES.

Theſe are commonly reckoned eight, ariſing from cauſes now to be mentioned.

* De Aere, Aquis, et Locis. † Gen. xxxi, ver. 35.

I. That

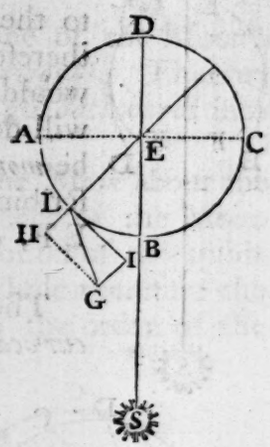


I. That *Variation*, whereby, if we ſuppoſe E the Earth, and the circle A B C D the orbit of the *Moon*, while the *Moon* deſcribes the quadrant A B, that is, while ſhe goes from the *quadrature* to the *conjunction*, the force tending towards the *Sun* at S, conſpires with the force tending towards the Earth at E, and therefore *accelerates* her motion. But while ſhe goes from the *conjunction* B to the next *quadrature* C, the force tending towards the Sun will act contrary to the force tending towards the Earth, and therefore will *retard* her motion.

In the ſame manner while ſhe goes from the *quadrature* C, to the next *ſyzygy* D, the ſame force, tending towards S, will *accelerate* her again, but while ſhe goes from thence to the *quadrature* at A, it will *retard* her again.

The Moon therefore in her monthly revolution about the Earth, is, by this action of the Sun, *alternately* accelerated and retarded.

II. This force tending towards the Sun being the DISTURBING FORCE, or that force which prevents the Moon from deſcribing about the Earth *equal areas* in *equal times*, will be greateſt at the OCTANTS.



For this force being reſolved into two others, after Sir *J. Newton*'s manner, *one* of them at the quadratures, or Syzygies, will be found to point *from*, or *towards*, E the center of the Earth directly, and therefore will not hinder the Moon from deſcribing equal areas in equal times; the *other*, likewiſe, in thoſe places will be found to tend towards the center of the Sun, and therefore neither of them will prevent the Moon there from deſcribing equal areas in equal times, i. e. will not at the quadratures diſturb the Moon's motion at all.

But when the Moon is in the *Octants*, as at L, this force, being reſolved into *two others*, one of them as L H will point *directly to*, or *from*, the center of the Earth, and therefore will *increaſe* or *diminiſh*, the Moon's tendency towards the Earth, but not hinder her from deſcribing equal areas in equal times. But the other as L I, or H G, points neither towards the *center* of the Earth, *nor* Sun, and therefore, in the *Octants*, prevents her deſcribing equal areas in equal times.

But

But this being the mid-way between the *quadrature* and the *ſyzygy*, in both which places this diſturbing force doth not prevent the Moon from deſcribing equal areas in equal times, it follows that at the *octants*, this *diſturbing force* will be *greateſt of all*.

And for this reaſon it hath always been found more difficult to obtain the Moon's place in the *octants* agreeing with obſervation, than at the *Syzygies*, or *Quadratures*.

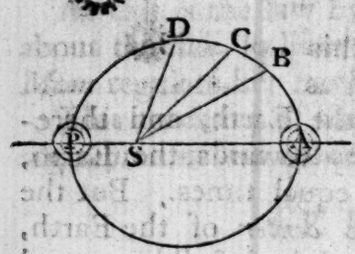


III. The Moon's orbit is more *curved* in the *quadratures* than in the *ſyzygies*.

For her motion being accelerated during her progreſs from the *quadratures* to the *ſyzygies*, in the *ſyzygies* her motion will be *quicker* than it ought otherwiſe to be, and therefore her *centripetal* force *leſs* than it would otherwiſe be. She will therefore at the *ſyzygies* deſcribe the portion of a a *larger* curve, which conſequently will be *leſs curved* than a ſmaller. That is, inſtead of deſcribing the curve A B, or C D, ſhe will deſcribe the curve E F, or G K.

On the other hand, while the Moon goes from the *ſyzygies* to the *quadratures*, her motion is continually retarded, and therefore, at the quadratures, her motion will be *ſlower* than it would otherwiſe be. At the *quadratures* therefore the Moon will deſcribe the portion of a *leſſer* curve, which therefore will be *more curved* than a *larger* curve. That is, inſtead of deſcribing the curve A B, or C D, ſhe will deſcribe the curve E F, or G K.

Therefore, at the *quadratures*, the Moon's orbit is *more curved* than at the *ſyzygies*.



IV. Since theſe *irregularities* in the Moon's motion proceed, as was ſaid, from the action of the Sun, it will follow, that where the action of the Sun is *greateſt*, the *irregularities* ariſing from it will be *greateſt* too. But the *nearer* the Earth is to the Sun, the *greater* will be the action of the Sun upon the *Moon*. And the *more* ſhe tends towards the Sun, the *leſs* will ſhe tend towards the Earth.

When therefore the Earth is at the *perihelion* P, and conſequently at its *leaſt* diſtance from the *Sun*, the action of the Sun upon the Moon will be

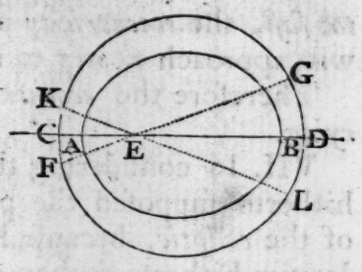
be *greateſt*, and deſtroy more of its tendency towards the Earth than at any other diſtance, as S D, S C, S B, &c.

Therefore when the Earth is at the *perihelion* P, the Moon will deſcribe a larger orbit about the Earth, than when the Earth is at any other diſtance from the Sun, and conſequently then, her *periodical* time will be the *longeſt*.

But the Earth is at its perihelion in the winter, and, conſequently, then the Moon will deſcribe the *outermoſt* circle about the Earth, and her periodical time will be the longeſt. And this agrees with obſervation.

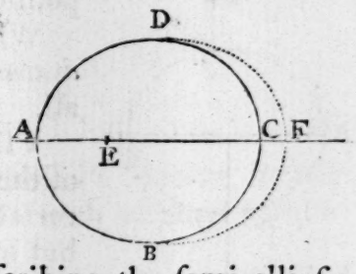
For the ſame reaſon, when the Earth is at its *aphelion* A, the tendency of the Moon towards the Earth will be the *greateſt*, and, conſequently her periodical time the *leaſt*. And in this caſe, which will be in the ſummer, ſhe will deſcribe the *innermoſt* circle about the Earth.

V. Since the Moon, from what has been ſaid, appears to deſcribe an *elliptical* orbit about the Earth E, in the Focus of it, and ſince her centripetal force towards the Earth, by means of the action of the Sun, is continually *increaſing*, or *decreaſing*, but not equably, that is ſometimes *leſs*, and ſometimes *more*, than in the *inverſe duplicate* proportion of the diſtance of the Moon from the Earth, therefore, in this caſe, the line of the Moon's apſids A B will be continually going *backwards*, or *forwards*. That is, the axis A B will not always lie in that ſituation, but go *backwards* into the ſituation K L, or *forwards*, into the ſituation F G.



Since however, taking one whole revolution of the *Moon* about the Earth, the action of the Sun *more diminiſhes* the tendency of the Moon towards the Earth than it *augments* it, therefore the motion of the apſids *forwards*, *exceeds* their motion *backwards*. Upon the whole therefore the *apſids* of the Moon's orbit go *forwards*, or according to the order of the ſigns.

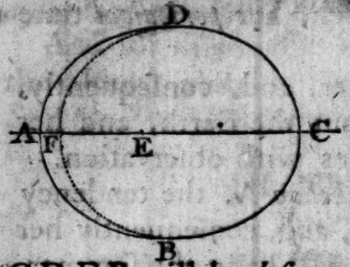
VI. Becauſe the Moon deſcribes an *eccentrical* orbit about the Earth at E, and the action of the Sun upon her ſometimes *increaſes* her tendency towards the Earth, and ſometimes *diminiſhes* it, i. e. makes her gravity towards the Earth *increaſe*, or *decreaſe*, *too faſt*; if while the Moon aſcends from her lower *apſid* A, her gravity towards the Earth decreaſeth *too faſt*, inſtead of deſcribing the ſemi-ellipſis A B C, and coming to the *higher apſid* at C, as ſhe would otherwiſe do,



ſhe

ſhe will run out in the curve B F D, and come to the *higher* apſid at F. But the curve A B F D is *more eccentric* than the curve A B C D.

Therefore when the gravity of the Moon towards the Earth *decreaſes* too faſt, the eccentricity of her orbit will *increaſe*.

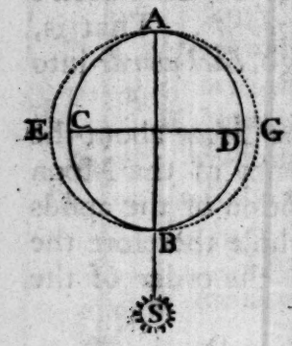


On the other hand, if the Moon is going from her *higher apſid* C to her *lower* A, and her gravity towards the Earth *increaſes too faſt*, inſtead of deſcribing the ſame ellipſis C D A, and ſo coming to the *lower apſid* at A, ſhe will approach nearer to the Earth, and deſcribe the curve D F B, and ſo come to the *lower apſid* at F. But the curve C D F B will be *leſs eccentric* than the curve D A B C.

Therefore, when the gravity of the Moon towards the Earth *increaſes too faſt*, the *eccentricity* of her orbit will *decreaſe*. And the orbit itſelf will approach nearer to a circle.

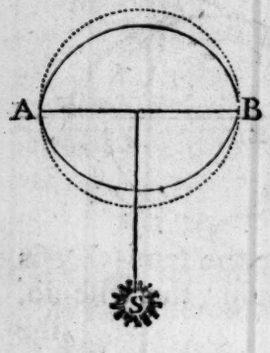
Therefore the *eccentricity* of the Moon's orbit will be *continually varying*.

VII. In conſidering the *irregularities* of the Moon's motion, we have hitherto ſuppoſed the plane of her orbit as coinciding with the plane of the *ecliptic*, becauſe her motion would be affected with the irregularities hitherto ſpoken of, if in reality it did ſo.



But it hath been before obſerved, that one half of the Moon's orbit A C B, is raiſed above the plane of the ecliptic A E B G, and the other half A D B *depreſſed* below it; and the *points* A B, where the Moon's orbit *croſſeth* the plane of the ecliptic, are called the NODES, and the line A B, joining thoſe points, is called the LINE of the NODES.

But when this Line of the Nodes A B lies in conjunction with the Sun S, it is at *reſt*, but in all other poſitions it goes *backwards*.



When this line of the Nodes A B lies in the *quadrature* with the Sun S, it goes *backward* faſteſt of all.

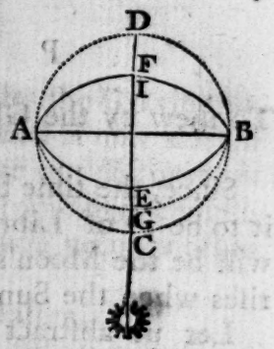
VIII. It hath been formerly obſerved that the orbit of the Moon is *inclined* to the plane of the ecliptic in a certain angle; but this angle is not *conſtantly* the ſame, but ſometimes *greater* and ſometimes *leſs*, depending upon the different poſition of the line of the Moon's nodes with reſpect to the Sun.

When



When the Line of the Nodes AB, paſſes through the *Syzygies*, the Plane of the Moon's Orbit produced paſſes through the Center of the Sun S, and, conſequently, not being affected by the action of the Sun, is then at its *greateſt* State, making an Angle with the Ecliptic of about 5° 18′.

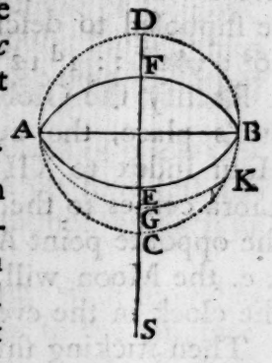
When the Line of the Moon's Nodes AB, lies in a Quadrature with the Sun S, then, ſuppoſing the Line ABCD to repreſent the Plane of the *Ecliptic*, and AEBF the Orbit of the *Moon*, let the Moon be ſuppoſed to have juſt now paſſed the *aſcending Node* at A, and going to her *Conjunction* with the Sun at E.



The Moon will then be going farther and farther from the Plane of the Ecliptic ABCD, and, was there *no action* of the Sun, would come in conjunction with him at E.

But, becauſe of the Action of the Sun, the Moon, in going from the *Quadrature* at A, towards her Conjunction, will be perpetually *drawn down* towards the Ecliptic, and therefore will not come to a Conjuction with the Sun at E, but at G, making an Angle with the Ecliptic GAC leſs than EAC.

But the Sun continuing ſtill to act, after the Moon has arrived at her Conjunction, will go on to *draw* her *down* towards the Ecliptic; by which means, ſhe will not croſs the *Ecliptic* at the Point B, her *former Node*, but in ſome other Point nearer to the Sun, as K.



But wherever the Moon croſſes the *Ecliptic* is her *Node*. Therefore, her Node, in the mean time, hath gone *backward* from B to K, and the Moon hath deſcribed a Semi-Orbit AGK, making a *leſs* Angle with the Ecliptic, than the Orbit AEB, which ſhe would have deſcribed had there been no Action of the Sun at all.

And now, before we diſmiſs this ſubject of the Moon's Motion, it will not be foreign to the purpoſe to add a few words with relation to the Phenomenon of

THE HARVEST MOON.

About the time of the Autumnal Equinox, when the Moon is at, or near the full, ſhe is obſerved to riſe almoſt at the ſame time for ſeveral nights together; and this phenomenon is called the *Harveſt Moon*.

This was taken notice of by country people, before it was at all attended to by philoſophers; and this hath not been till very lately. The firſt perſon that is ſaid to have accounted for it, was Mr. *Johnſon* *.

From hence we may form the following

PROBLEM.

To ſhew by the Globe the phenomenon of the Harveſt Moon.

Since, the time being given, the place of the Sun is given, let us ſuppoſe it to be 1° of Libra, the point oppoſite to which is 1°. of Aries. This will be the Moon's place, ſhe being then at the full, and conſequently riſes when the Sun ſets.

Let us abſtract at preſent from the inclination of the Moon's orbit, and ſuppoſe that ſhe performs her menſtrual revolution about the Earth in the Ecliptic, and likewiſe that her motion in it is equable.

The Synodical month, as obſerved before, conſiſts of 29½ days, therefore on the Globe, where accuracy is not to be expected, the Moon may be ſuppoſed to deſcribe the Ecliptic (360°) in thirty days. Therefore $30^d : 360^\circ :: 1^d 12^\circ$ = the Moon's motion in the Ecliptic in one day.

Rectify the Globe for the latitude of the place, and, bringing the Sun's place, the beginning of Libra, to the braſs Meridian, ſet the Hour Index to XII at noon; then turning the Globe weſtward, when Libra comes to the weſtern ſide of the Horizon, i. e. when the Sun ſets, the oppoſite point Aries will be found on the eaſtern ſide of the Horizon, i. e. the Moon will be riſing, and the Hour Index will point to VI of the clock in the evening.

Then ſticking ſmall black patches at Piſces 18°. and Aries, and Aries 12°. and Aries 24°. for the Moon's place four ſeveral nights, when thoſe patches come to the eaſtern edge of the Horizon, the Moon will be riſing. But the Hour Index will, at all thoſe times, point nearly to VI o'Clock. And therefore the Moon, for thoſe *four* nights, will riſe *nearly at the ſame time*.

* In his Quæſtiones Philoſ. edit. 2da pag. 124.

The

The inclination of the Moon's way to the Ecliptic, and the different poſition of her Nodes, will make ſome alteration in this phenomenon. It is ſufficient to ſee the nature of it, in general, from whence all the particular caſes will be more readily underſtood.

Having treated of the Fixed Stars, and what concerns their apparent motions; and, but juſt now, of the actions of the Sun and Moon, as the cauſes of Tides in the Ocean and Atmoſphere; it naturally follows, that we add ſomething relative to another ſort of bodies which are ſometimes found to viſit us, and thoſe are

C O M E T S.

For, as we have ſeen already, that Tides are cauſed by the Gravitation of our Waters towards the Sun and Moon, and Gravitation is now known to be an affection of all Matter, as far, at leaſt, as we can diſcover, it will follow, that Comets, if large enough, and if they come near enough to us, may, by the ſame principle, produce the ſame, and perhaps other effects.

What thoſe effects may poſſibly be, will be ſeen hereafter.

In the mean time we may obſerve, that *Seneca*, and, before him *Cleomedes*, ſuſpected that there might be more Planets than thoſe *ſeven* which were commonly known in their time. And theſe ſuſpicions have been ſince abundantly confirmed; firſt, by the diſcovery of the Satellites attending Saturn and Jupiter, and afterwards by the whole doctrine of Comets.

Comets were, in general, by the followers of *Ariſtotle*, looked upon as meteors, and ſudden exhalations; and therefore it is no wonder if they have left no obſervations at all relating to them.

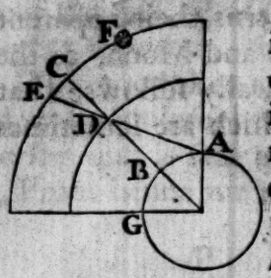
Some of the *Pythagoreans*, according to *Plutarch**, looked upon Comets as bodies returning at certain periods of time, and yet have left nothing concerning their periods, or even the paths deſcribed by ſuch as fell under their notice.

The firſt perſon that deſcribed the path of any Comet, with tolerable exactneſs, was *Peter Appian*, profeſſor of mathematicks to the emperor *Charles* V. and his brother *Ferdinand*. So that æra is the higheſt to which this part of aſtronomy can pretend to go.

Having an opportunity of obſerving no leſs than five Comets, between the years 1531, and 1539, he was the firſt perſon tnat diſcovered that their tails were always turned towards that part of the heavens which is oppoſite to the Sun.

* De Placit. Philoſ. lib. 3, c. 1.

At laſt, a Comet appearing in the year 1577, it was obſerved by *Tycho Brahe*, already mentioned, to have no diurnal Parallax. From whence it was plain, this Comet was farther from the Earth than the orbit of the Moon, and therefore could not be a Meteor or Exhalation.



Let ABG be a Meridian, or great circle of the Earth, in which let A be *Uraniburgh*, where this Comet was obſerved by *Tycho*, and B *Prague*, in *Bohemia*, where it was obſerved by *Hagecius*. Theſe two places lie nearly in the ſame Meridian, but differ in Latitude ſix degrees,

Let D be the Comet, and F the bright ſtar in the *Vulture*. To an obſerver at A, the Comet, ſuppoſing it had a Parallax, would appear amongſt the fixed Stars at E, and its diſtance from F would be the arch FE: But to an obſerver at B, the place of the Comet would appear amongſt the fixed Stars at C, and its diſtance from F would be the arch FC.

But, both *Tycho* and *Hagecius* obſerved this Comet, when in the ſame verticle circle, and meaſuring its diſtance from the Star F, found it to be the ſame. Conſequently, the arch CE vaniſhing, the angle CDE, that is ADB vaniſhed, or was = 0.

But the Moon ſeen from the places A and B, would appear at different diſtances from the Star F. Therefore this Comet was farther from the Earth than the orbit of the Moon. W. W. D.

The principal queſtions relating to Comets may be reduced to the following heads. Their NUMBER,----MAGNITUDES,----MOTIONS,---- and USES.

I. NUMBER.

As, by the *Ariſtotelian* philoſophy, the world was taught to look upon Comets as nothing more than Meteors, their number was eſteemed infinite. And as this part of Aſtronomy hath been but little cultivated, till within theſe few years, in compariſon, and few obſervations have been made on them with any tolerable acccuracy, it cannot be expected that their number ſhould be, as yet, exactly determined. In Dr. Halley's Tables, is a catalogue of twenty-four Comets, obſerved between the years 1337, and 1698 incluſively. In the French edition of theſe Tables, is a ſupplement to that catalogue of twenty-eight more, obſerved between the years 1264, and 1757, incluſively. And a few others have been ſeen ſince that time.

MAGNI-

II. MAGNITUDES.

Theſe, like the magnitudes of the planets, are different. The Comet of 1680, from Mr. *Flamſteed*'s obſervations, ſeems to have been little more than ten times as big as our Moon, or one fourth part as big as our Earth*.

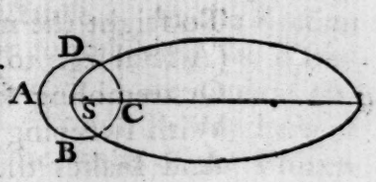
III. MOTIONS.

They are now known to be bodies of the Planetary kind, but,

I. Not, like the Planets, moving all in *one* direction; that is, having their proper motion from *Weſt* to *Eaſt*, or according to the order of the Signs; but ſome of them moving from *Eaſt* to *Weſt*, or contrary to the order of the Signs.

II. Not, like the Planets, confined within a *Zodiac*, but having the planes of their orbits inclined to that of the *Ecliptic*, in a great variety of angles. The inclination of the Comet's orbit that appeared in 1680, was 60°. 56′. and that of 1683, was 83°. 11′.

III. The orbits of the Planets, tho' ellipſes, differ but little from circles, whereas thoſe of the Comets are very excentrical, as here. The Comet of 1680 came almoſt in a ſtrait line into the very body of the Sun, and then returned up again, nearly in another.



IV. As ſome Comets are pretty well known to have returned at certain intervals of time, they muſt have deſcribed orbits *returning into themſelves*, which muſt be ellipſes. Yet Comets, paſſing by ſuch large bodies as Jupiter and Saturn, may have their velocities increaſed, though but a little, in ſuch a manner, as ſhall be ſufficient to change their elliptical orbits into parabolic ones, ſo as *never* to return again. Or, if they do return, their periodical times may be altered, ſo as to become longer, or ſhorter.

V. As Comets croſs the Ecliptic, or the line of the Earth's way A B C D, round the Sun S, they will have their Nodes as well as the Moon. And therefore, in certain poſitions of the Earth, Comets may have the ſame effect with the Moon, in cauſing Eclipſes of the Sun. Or, if their apparent diameters are too ſmall, they may appear as black ſpots going

* Whiſton's New Theory of the Earth, pag. 190.

going over the body of the Sun, as the two inferior planets Venus and Mercury have been ſeen to do.

VI. The periodical times of ſuch Comets as are known to return, are different, like the Planets. The Comet of 1531 appears to have a period of about 754 years, having been ſeen afterwards in the years 1607, 1682, and is now expected to return this year, 1758.§

The Comet of 1680, hath a period of about 575 years; and ſeems to be the *Julium Sidus*, taken notice of by the Roman poets, having appeared the year before *Chriſt* 44, ſoon after *Julius Cæſar* was murdered in the Senate-houſe; and, perhaps, is the ſame that *Homer* alludes to, as it would have appeared the year before *Chriſt* 619.

Οιον δ' Αςέρα ἦκε Κρόνου παῖς ἀγκυλομήτεω
Η Ναύῃσι τέρας, ἢε Στρατῷ εὐρείῃ Λαῶν
Λαμπρὸν, τῷδέ τε πολλοὶ ἀπὸ Σπινθῆρες ἴενται*.

Fir'd with the charge, ſhe headlong urg'd her flight,
And ſhot like lightning from Olympus height.
As the red Comet, by *Saturnus* ſent,
To fright the nations with a dire portent;
(A fatal ſign to armies on the plain,
Or trembling ſailors on the watry main.)
With ſweeping glories glides along in air,
And ſhakes the ſparkles from its blazing hair.

This Comct, at its greateſt diſtance, is about 11,200,000,000 of miles from the Sun; and at its leaſt diſtance from the Sun's center, which is 490,000 miles, was within leſs than a third part of the Sun's ſemidiameter from his ſurface.

In that part of it's orbit which is neareſt the Sun, it flies at the amazing ſwiftneſs of 880,000 miles in an hour; and the Sun, as ſeen from it, appears 100 degrees in breadth, and conſequently 40,000 times as large as he appears to us †.

If any body was projected from the Sun with a velocity equal to that of a cannon ball, i. e. ſuch as would make it fly 480 miles in an hour, it would but reach the Aphelion diſtance of this Comet in 2660 years.

Amazing as this diſtance is, yet it is inconſiderable in compariſon of that of the fixed Stars. For the ſame body, with the ſame velocity, would be, in reaching the neareſt fixed Star, 7,600,000 years ‡.

§ And ſo it did. See Tab. Aſtronom. de Mr. Halley, par M. Delalande, à Paris, 1759.
* Iliad iv. v. 75. † Ferguſon's Aſtron. p. 27. ‡ Ferguſon, ut ſupra, p. 26.

IV. USES.

As the Cometic part of Aſtronomy hath begun to be cultivated but ſo lately, in compariſon, it is not ſurprizing, if we are hitherto intirely at a loſs in our conjectures, as to the purpoſes for which they are deſigned.

As ſome of them are found to approach ſo near the Sun at their Perihelions, and then to make ſuch long excurſions from him at their Aphelions, it is difficult to conceive how ſuch very different degrees of heat and cold, can conſiſt with vegetable or animal bodies. Conſequently how far they are capable of being inhabited, muſt appear a doubt. If they are, it muſt be by creatures of a very different texture and compoſition from ourſelves.

Dr. *Gregory*, in his Aſtronomy*, ſuppoſes they may be deſigned, by falling into the Sun, to repair his loſt feuel; or, by involving the Planets in their tails, to reſtore the fluid parts of their bodies, exhauſted continually, and turned into ſolids. A fact, which, however it might have been doubted of formerly, yet now, that the fluid parts of our earth, in particular, diminiſh, appears from ſeveral circumſtances. In the Ruſſian account of the voyages from *Aſia* to *America*, for compleating the diſcovery of the North-eaſt Paſſage †, it is remarked, that "the general obſervation, that the water of the ſea decreaſes, proves alſo true here of "the Frozen Sea. There is to be ſeen along the coaſts of the Frozen "Sea, wood caſt on ſhore, on ſuch heights, that, now-a-days, are not "to be reached by any flood or waves."

But if this be ſo, it will appear, that every primary Planet may be conſtantly increaſing in bulk, by an acceſſion of freſh matter; from whence it will follow, that the Orbit of its Satellite, if it hath any, will be contracted §, and its periodical time ſhortened, by an increaſe of its centripetal force.

Another conſequence, if not an uſe, of this motion of Comets will be, that in paſſing by any Planet, as it croſſes its orbit, it may accelerate or retard that Planet's motion, and conſequently change its orbit, and, with that, its periodical time.

But as the motion of the Comet itſelf, for the ſame reaſon, may be accelerated, or retarded, the form of its orbit may be changed; nay it may be accelerated in ſuch a manner, eſpecially in paſſing by ſuch large Planets as Jupiter and Saturn, that the centripetal force towards the Sun may become too weak to fetch it round again. From whence it will

* Pag. 481. † Pag. 23. § See Gregory's Aſtron. lib. I. prop. XLIX.

follow,

follow, that it will never return, but proceed forward, with the projectile force it has acquired, till it meets with ſome other ſyſtem, where it may become a new Comet, or perhaps a Planet, either primary or ſecondary. And by this means, a Comet, though whilſt in that ſtate it ſeems unfit for vegetable or animal life, may, under the direction of the ſupreme cauſe of all things, become an habitable world, the proper receptacle for intelligent and moral agents.

In its paſſage by a Primary Planet attended by a Secondary, it may ſo affect the motion of the latter, as to make it leave its Primary, and become itſelf a Primary, revolving round the Sun.

A Comet likewiſe, in paſſing by a Planet, may produce in it alterations of the greateſt conſequence to its Inhabitants, by attracting its Waters, and cauſing extraordinary tides and deluges; or, by being heated to ſuch an extraordinary degree at its Perihelion, as in its return from thence, to cauſe the deſtruction of all animal life, or perhaps a general conflagration*.

As the uſes for which ſuch extraordinary bodies are deſigned are unknown to us, we can only reaſon upon them from the known laws of Matter and Motion. Such wonderful bodies were not made in vain, and we may be aſſured they are intended, at proper times, to anſwer the wiſeſt and beſt purpoſes.

" I ſuſpect, ſays Sir *Iſaac Newton*†, that that Spirit, which, though " it conſtitutes the leaſt, is yet the ſubtileſt and beſt part of our Air, " and neceſſary to the life of every thing, for the moſt part ariſeth from " Comets." If it doth ſo to us, why may it not do the ſame to the inhabitants of the other Planets?

But, leaving conjectures of ſo remote a nature, they will not improperly lead us to others, with which we are more intimately concerned.

The firſt of theſe relates to the

* See Gregory's Aſtron. pag. 481. † Princip. p. 515.

MOSAIC

MOSAIC HISTORY OF THE CREATION.

This having been misrepresented by many, and mistaken by most, it will not, however it may seem, be quite foreign to the present subject, to add a few words here, that may help to explain or illustrate it.

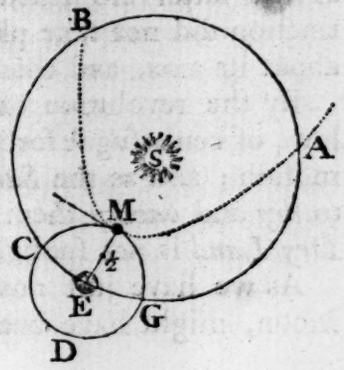
In the first place, then, it may be proper to observe, that the first chapter of *Genesis* doth not seem to be the history of a *Creation*, properly so called. It was sufficient to say, in general, that *Matter* was not *eternal*; and therefore, that "*In the beginning* (whenever that was) *God created the Heavens and the Earth.*"

As we are unconcerned with any other parts of the system besides our own, the only thing necessary to be remarked by the historian, in the next place, was the *Condition* in which the Planet *Mankind* were about to inhabit was, at the time when first reduced into *habitable* order. The Earth, therefore, is described to have been then "*without Form, and void, and Darkness to have been upon the face of the Deep.*" That is, it was in a perfectly *chaotic* state. The word *Chaos* itself signifying nothing more than *Darkness*.

In order to dispel that vast mass of vapours, and the dense Atmosphere that caused this *Darkness* upon the *interior* parts, or *nucleus*, as it may be called, or as it was just stiled *the face of the deep*, some Agent or other was necessary. And as Providence commonly employs mechanical causes, that Agent was probably the Moon.

For, as we have seen already that the Moon is *now* capable of raising Tides, not only in the Waters, but likewise in the Atmosphere, so must she have been *then* too. For the *same* cause, under the *same* circumstances, will always produce the *same* effects.

It is not said that the matter of the Moon was then *created*, any more than that of the Earth. The Moon therefore might *then* have *first* become a *Satellite* to our Earth, as before that, she might have been a *Comet*, revolving in an ellipsis, about the Sun.



Let S be the Sun, BCGA the orbit of the Earth revolving about the Sun in its *chaotic* state, and AMB the orbit of the Moon about the Sun in its *cometic* state.

When the Earth was in a point in its own orbit, as E, let the Moon, as a Comet, have deſcended along the line AM to M.

Since Comets and Planets are all of them retained in their orbits by a *centripetal* and *projectile* force, if at the point M, on account of its nearneſs to the Earth, the *Gravity* of the Cometic-Moon towards the Earth at E, ſhould exceed its Gravity towards the Sun at S, and the *projectile* force acquired at M, in deſcending along the line AM, ſhould be equal to the *Velocity* which it would acquire by the force of Gravity towards the Earth, in falling freely from reſt at M, through half the line EM, joining the centers of the Earth and Comet, that Comet would no longer be a Comet deſcribing the line AMB about the Sun, but would become a *Satellite*, i. e. a *Moon*, to the Earth at E.

The *Satellite* being formed in this manner, and beginning to clear the *Atmoſphere*, would let in upon the *Nucleus* ſome *Glimmering* of light, expreſſed by the command, "*Let there be Light.*"

And as the *chaotic* Earth turned round its own axis, ſo that every Meridian ſucceſſively came into the Light, it furniſhes a reaſon why, tho' no *Sun* is yet mentioned, yet "the *Evening* and the *Morning* are ſaid to "be the *firſt Day.*"

If we ſuppoſe the Moon became a *Satellite* to the Earth at the *Conjunction*, the *joint* forces of the Sun and Moon there would not only be greater in diſpelling the vapours, than had ſhe done ſo in any other poſition, but likewiſe it will give a reaſon why ſhe is not mentioned till the *fourth Day*, when ſhe muſt have appeared *horned*, in the *Evening* after *Sun-ſet*, under any Meridian.

The vapours being *diſpelled*, and now formed into *Clouds* by the *Actions* of the *Sun* and *Moon*, would form a *Diſtance*, or *Space*, between them and the denſer particles of Water adhering ſtill to the *Nucleus*. This ſpace is called the רקע or *Expance*, but improperly tranſlated the *Firmament*. By the firſt of theſe are meant the Waters *above the Firmament*, as the latter are ſtiled the Waters *under the Firmament*. But this diſtinction did not take place till the Earth had made a compleat revolution about its axis, and therefore is mentioned on the *ſecond Day*.

By the revolution of the Earth about its own axis, from the known laws of centrifugal forces, the denſer parts would retire from the axis of motion; and as the *Sun-beams* were now let in through the *Atmoſphere*, to *dry* and *harden* them, we have a plain and ſufficient reaſon why the *Dry Land* is not ſpoke of, as *appearing* before the *third Day*.

As we have juſt now ſuppoſed that the Planet, at preſent called the Moon, might have been originally a Comet, performing its revolutions, like

like the reſt, about the Sun placed in the focus of its elliptical orbit, and that it might have been a principal agent, under Providence, in forming this Earth of ours into a *Habitable World*, ſo likewiſe might ſome other *Cometic Body* have been a like agent, in introducing the cataſtrophy of

THE GENERAL DELUGE.

This is another point in Scripture hiſtory, that hath not been underſtood, and properly attended to.

The point in queſtion, and to be reſolved firſt, is, whether there remain ſufficient evidences of the fact itſelf: and in the next place, whether any cauſes can be aſſigned, ſufficient to produce ſuch an effect.

The firſt depends upon arguments taken from Natural Hiſtory. Such are the *Shells* of *Sea-fiſh*, *Bones* of *Animals*, intire *Vegetables*, or Parts of them, found at great depths under ground, and incloſed, ſometimes, in the moſt ſolid and compact bodies. And in other places, on the tops of the higheſt hills, in the remoteſt Parts of the known world.

Doctor *Plott*, in his Hiſtory of *Staffordſhire**, quotes the author of a treatiſe, called *Mercurius Centralis*, who mentions "the Maſt of a Ship "with a Pully hanging to it, dug out of the top of an high hill in "*Greenland*."

"But the moſt prodigious ſtory (adds he) we have of this kind, is "that of *Baptiſta Fulgoſus*, *Ludovicus Moſcardus*, and *Theodorus Moretus*, "who tell us, that at the village of *Bern*, in *Switzerland*, anno 1460, "in a mine, fifty fathoms deep, there was dug up a whole Ship, with "its Anchors, and broken Maſts, in which were the Carcaſes of forty "Mariners, with their Merchandiſe; which *Fulgoſus* more particularly "tells us, as a thing done in his own time, and ſeen by many grave "and ſober men, who were eye-witneſſes of the fact, and from whom, "he ſays, he received a perſonal account of it."

It is hard to controvert matter of fact, and eſpecially when it comes well atteſted; and yet, this account, it muſt not be diſſembled, hath greatly the air of a fiction. It is therefore only mentioned here as a remarkable piece of hiſtory, without laying any greater ſtreſs on it than it deſerves.

That Sea-ſhells were found at the diſtance of ſome hundreds of miles from the ſea ſide, together with the difficulty of accounting for them, was taken notice of long ago by *Eratoſthenes*, as we learn from *Strabo*†.

* Chap. ii. § 71. † Pag. 84.

And what mighty Fiſh bones are found, when the mountain tops are waſhed down in *Tartary*, may be ſeen in the *Muſcovite Ambaſſador*'s own account of his travels through thoſe countries*.

Waſer, in his Voyages†, ſpeaking of *Copayapo*, a very high hill in *Chili*, in about Lat. 26° South, ſays, "the place were we ſate was covered with ſand, and Sea-ſhells of divers ſhapes and forms; though indeed, which I wondered at, there were no Shell-fiſh on the ſhores all along this whole coaſt. I have landed at many places of it, but could never find any. When we had reſted ourſelves in this place, which was, as near as we could compute, eight miles from the Sea, and *at leaſt a mile* in perpendicular above it, we looked, &c."

And Doctor *Mounſey*, phyſician to the Czarina's army, in his account of the Salt Mines, near *Cracau*, in *Poland*, A. D. 1749, ſays, "Notwithſtanding there is no remembrance, or tradition of any remarkable accident, by the falling in of theſe mines, yet they have lately diſcovered a Wooden Houſe, which muſt have been ſwallowed in long ago. Theſe mines were on fire in the year 1644, but this accident muſt have happened long before that time; for they have a plan of theſe works, taken about two hundred years ago, with remarks of every thing that was curious in all three contignations; but no mention is made of this houſe, nor is there any thing in the regiſters of theſe works, that ſhews it to have ſunk in ſince. The wall of this houſe is ſeen at the ſide of one of the croſs-ways. They have found plates, ſpoons, and other things of metal; but they make no farther ſearch, as the pains would exceed the profit: and ſo it is left as a curioſity."

And a little afterwards he adds, "They find in theſe mines *Alabaſter*, *Glacies Mariæ*, *Gypſum*, and ſometimes *Pectines*, or ſmall *Sea-ſhells*. But the moſt remarkable thing of all is, in the middle of a vaſt ſalt rock, a large Tree is found, with all its branches incaſed in it, lying horizontally. I ſend you a piece of it, which I hewed out of the rock myſelf. It ſeems to be a Beech tree, of which there grow plenty in theſe countries at preſent‡."

From theſe, and numberleſs other inſtances of the like nature, it ſeems as if this Earth had been formerly in a fluid ſtate, by which means bodies of very different kinds had been mixed together. That theſe bodies are found, not only at vaſt depths, but likewiſe at vaſt heights, not only incloſed in the ſolid ſubſtances of other bodies, but ſingle, or

* See *Yſbrant Ides*'s Travels from *Moſcow* to *China*, pag. 25, 26. † Pag. 203,
‡ Philoſophical Tranſactions, No. 493.

in

in ſtrata, which conſequently muſt have been brought there by the ſea covering thoſe parts.

The evidences therefore of the fact appear very ſtrong in behalf of the Deluge, the only thing remaining, is to find a cauſe adequate to the effect.

The cauſes aſſigned for this effect are two.

I. A Forty Days Rain.

II. That then the *Fountains* of the *Great Deep* were broken up.

By this Rain, and this Eruption of the Subterraneous Waters, or, of the Abyſs, it is ſaid that the *Tops* of the *higheſt Hills* were *covered*.

The queſtion is, where we can find a ſtock of water ſufficient for this, and what became of it afterwards?

Doctor *Halley*, how little ſoever he was inclined to favour ſuch a ſubject as this, yet allows*, "that a change in the Earth's center of gravity, "but the 2000th part of the radius of the Earth, would be ſufficient to "bury the tops of the higheſt hills under water."

Suppoſing then this center of gravity removed for a time towards the then *inhabited part* of the world, (with him) we ſee in what manner a *Deluge* was poſſible.

But as this *Deluge* is ſuppoſed only to have been *partial*, whereas there are evidences of its *univerſal extent* all over the world, and the *two cauſes* above aſſigned are not taken into the account at all, we are at liberty to ſearch a little farther.

We ſaw before, in ſpeaking of the *Uſes of Comets*, that as they croſs the Planetary Orbits, ſo it is not impoſſible but they may paſs ſo near to ſome particular Planet, as to involve it in their *Tails*, and that this may be the cauſe of *immoderate* and *unuſual Rains*.

It is not impoſſible, likewiſe, as was obſerved in the ſame place, but that ſuch a Comet, in paſſing near a Planet, may raiſe *extraordinary Tides* in its waters. And this will be not only in ſuch as float upon its ſurface, but ſuch likewiſe as communicate with them, whether they be ſuppoſed to be *central* waters, or ſuch as are contained in *Caverns* and *Interſtices*.

* Miſcel. Curioſ. vol. 1. pag. 307.

Theſe

Theſe being violently ſwelled by this adventitious force, will break the upper cruſt of the Earth, and joined to the *forty days Rain*, contribute to the forming that maſs of waters, which might well cover the *tops of the higheſt hills*.

The Comet of 1680 performs ſeven revolutions in about 4028 years. But this is the interval between its appearance in 1680 and the *Deluge*. And this, of all the Comets known, paſſes the neareſt to the annual orbit of the Earth. If then it paſſed by the Earth at a proper diſtance, on the Seventeenth Day of the Second Month from the Autumnal Equinox, in the 2349th year before the Chriſtian æra, when "the fountains of "the great deep were broken up, and the windows of heaven were "opened," then, as Mr. *Whiſton* well obſerves*, we have found the true and *adequate cauſe of the Deluge*.

Doctor *Halley*, ſpeaking of this very Comet, ſays, "none hath threat-"ned our Earth with a nearer appulſe than that of 1680. For, by cal-"culations, I find that *Nov.* 11^{d} 1^{h} 6′ P. M. that Comet was not above "the ſemidiameter of the Sun to the northward of the way of the Earth. "At which time, had the Earth been there, the Comet would have had "a Parallax equal to that of the Moon, as I take it. This is ſpoken to "aſtronomers; but what might be the conſequences of ſo near an ap-"pulſe, or of a contact; or, laſtly, of a ſhock of the celeſtial bodies, "(which is by *no means impoſſible* to come to paſs) I leave to be diſcuſſed "by the ſtudious of phyſical matters†."

We may now paſs on to

THE FIGURES of the EARTH, AND OF THE OTHER HEAVENLY BODIES.

As the heavenly bodies do not, probably, conſiſt intirely of ſolid matter, but are partly fluid, and partly ſolid, like our Earth, being, as is moſt reaſonable to conjecture, inhabited like it; ſo, if they revolve about their axes, which is no leſs neceſſary for cauſing the viciſſitudes of Day and Night, in order to repair the expence of animal ſtrength, as well as for

* New Theory of the Earth, pag. 186. † Miſcel. Curioſ. vol. 2, pag. 344.

for other uſes, all their parts will endeavour to recede from the axis of their motion.

By this means, the *equatoreal* parts, where the motion is ſwifteſt, will tend *leſs* towards the center than the reſt. Their endeavour to fly off from the axis about which they revolve, in part diminiſhing their tendency towards the center, thoſe parts, by their leſs gravity, will become *lighter* than ſuch as are nearer the Poles. The *polar* parts, therefore, will preſs in towards the center, and raiſe the *equatoreal* parts, till the quantity of matter about the Equator is ſo far increaſed, as to compenſate for its lightneſs, and an equilibrium will be reſtored. And on this account, the form they will aſſume will be that of an *Oblate Spheroid*, whoſe ſhorteſt axis paſſes through the Poles.

All other circumſtances remaining the ſame, the *faſter* the bodies revolve, the *more oblate* will their form be, i. e. the *more flat*, or *depreſſed*, will their *polar parts* be.

Thus much holds good in general of all the Planets. This *oblate* form is found, by obſervation, to obtain in the Planet Jupiter. For, as he turns about his own axis in leſs than ten hours, his *polar diameter* is to his *equatoreal*, according to Mr. *Flamſteed* and Mr. *Caſſini*, as 7 : 8.

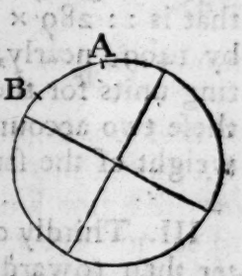
In the Moon, whoſe motion about her axis is ſo very ſlow, being performed in the ſame time with her *menſtrual* revolution about the Earth, this *difference* in her *diameters* is not ſenſible.

There is no method of proving this *oblate ſpheroidical* figure with regard to the Earth, by direct obſervation, as was ſeen of Jupiter; yet it is abundantly confirmed by other ſorts of obſervations made on Pendulum Clocks, at different diſtances from the Equator.

For, if *Gravity* was the ſame at all places, bodies would fall in a ſecond of time through equal ſpaces, in *all* places, or latitudes.

Conſequently a Pendulum Clock that ſhews the true time at *London*, or *Paris*, would do the ſame every where elſe.

Let A and B be two places in different latitudes. And let a Pendulum at A ſhew the true time, but when carried to B let it go too ſlow. In order then to make it ſhew the true time at B, the Pendulum muſt be ſhortened. For the ſhorter the Pendulum is, at the ſame place, the quicker will be its vibrations.



In the year 1672, Mr. *Richer*, at the iſland of *Cayenne*, in Lat. 4 deg. North, found that his Clock, which at *Paris* kept true time, now loſt 2′ 28″ every day. So that to make it go faſter, and bring it to *mean* or *equal* time, he was obliged to ſhorten it *one* line, or the twelfth part of a *Paris* inch.

And

And Doctor *Halley* ſays, that "at St. *Helena*, in Lat. 16 South, he "found that the Pendulum of his Clock, which vibrated ſeconds, need-"ed to be made ſhorter than it had been in *England*, by a very ſenſible "ſpace, (but which at that time, ſays he, I neglected to obſerve accu-"rately) before it would keep time; and ſince, the like obſervations "have been made by the *French* obſervers near the Equinoctial.

"Yet I dare not affirm, (adds he) that in mine it proceeded from any "other cauſe than the great height of my place of obſervation, above "the ſurface of the ſea, whereby, the gravity being diminiſhed, the "length of the Pendulum, vibrating Seconds, is proportionably "ſhortened*."

This ſhews the Doctor's great accuracy and caution. But as there can be no doubt of a fact, eſtabliſhed by ſo many concurrent experiments, it may be ſet down, as certain, that bodies at the Equator are lighter than at the Poles.

And this they will be on a threefold account.

I. From the centrifugal force there; which will be in the proportion of 289 to 288. That is, by means of the rotation of the Earth about its axis, a body which at the Poles would weigh 289 pounds, would, if carried to the Equator, loſe *one* pound, and weigh only 288 pounds.

II. Secondly, on account of the ſpheroidical figure of the Earth, ariſing from the diurnal rotation about its axis, from whence, if the Earth were homogeneous throughout, or equally denſe, bodies at the Equator would loſe *one* pound in 1121. That is, a body that at the Poles would weigh 1121 pounds, if carried to the Equator, would weigh only 1120.

On theſe two accounts, therefore, the weight of bodies at the Poles, is to the weight of the ſame bodies at the Equator :: 289 : 288 + 1121:1120 that is :: 289 × 1121 : 288 × 1120 :: 323969 : 322560, which dividing by 1409, nearly, their common diviſor, gives 229,9 and 228,9,or putting units for the decimal 9, it will be 230, and 229. Therefore, on theſe two accounts, the weight of bodies at the Poles, will be to the weight of the ſame bodies at the Equator, as 230 : 229.

III. Thirdly on account of the greater denſity of the Earth at the center than towards the ſurface, but in a proportion not yet ſufficiently determined, for want of knowing the exact length of a Pendulum that ſwings ſeconds at the Poles.

It

* Miſcel. Curioſ. vol. 1, p. 307.

It is farther to be obſerved, that the great warmth of the air, near the Equator, increaſes the length of a Pendulum there; it being the well-known property of *heat* to *expand* metals, and of *cold* to *contract* them.

On this account alone, therefore, it would be neceſſary to ſhorten Pendulums at the Equator.

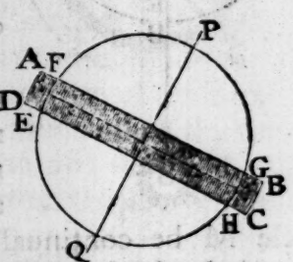
But this, as may be gathered from the obſervations of *Pitcarn*, and *De la Hire*, cannot be, between our latitude and the Equator, above one-fortieth part of an inch. For, as *De la Hire* obſerved, there were but two-thirds of a line difference between an iron rod ſix feet long, expoſed to the *froſt* and the *ſummer's ſun*.

When therefore it is ſaid, that it appears as the reſult of many experiments compared together, that a Pendulum at the Equator, ſwinging ſeconds, ought to be about *one-ſixth* part of an inch ſhorter than at *Paris*, the laſt cauſe, *the warmth of the air*, is taken into the account, as well as the *three* former.

In our latitude of *London*, a Pendulum thirty-nine inches and two-tenths, *Engliſh* meaſure, from the centre of the ball to the point of ſuſpenſion, will perform *one* vibration in *one ſecond* of time; that is, 3600 vibrations in an hour*.

Since the Equatorial parts of the Earth are *higher* than the Polar parts, as hath been obſerved, it will follow, that the *additional* matter under the Equator, by which the Equatorial diameters exceed the axis, or Polar diameter, may be looked upon as a ring encompaſſing the Earth at the Equator.

If the figure here annexed P G Q F repreſents a ſection of the Earth through any meridian, and that ſection be ſuppoſed to turn round the axis P Q, it will repreſent the globe of the Earth, with the ring A B C D, adhering to its Equator.



This conſideration being admitted, we ſhall be able to *explain* and *account* for *two* remarkable phenomena of nature; the *Proceſſion* of the *Equinox*, and the *Nutation* of the *Earth*'s *Axis* to the Plane of the Equator.

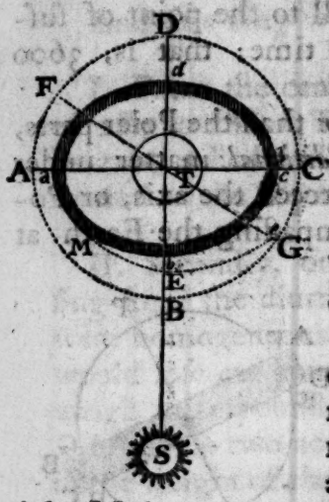
The uſe to be made of the Preceſſion of the Equinox was ſeen long ago, when we were ſpeaking of *Ptolemy*, the author of the *Syntaxis*. In what manner the *ſlow motion* of the fixed Stars *forward* was diſcovered, we ſaw when ſpeaking of *Hipparchus*, but how to account for it, from the *motion* of the *Equinoctial Points backward*, was firſt taught by Sir *Iſaac Newton*.

* Deſagulier's Philoſophy, vol. 1, pag. 373.

Whether the inclination of the Earth's axis to the plane of the Ecliptic hath been in all ages the ſame, hath been made a queſtion, as we ſaw before. If it gradually decreaſes, it is but very ſlowly, as was obſerved, and therefore it may, for a conſiderable time, be looked upon as *conſtant*, or the ſame. Therefore, though during the ſpace of any one year, this angle may be ſaid to be *invariable*, yet we ſhall find, that this can only be properly underſtood of it, as it is at the *two Equinoxes*. For at all other ſeaſons of the year, and particularly at the *two Solſtices*, it will be different, though very inconſiderably. This is called the *Nutation* of the Earth's axis, and will be eaſily apprehended, when we have conſidered the nature of the

PRECESSION OF THE EQUINOX.

And this, after what hath been ſaid on the *Lunar Irregularities*, will be eaſily underſtood likewiſe.



Let ABCD be the plane of the Ecliptic, in which is the Sun S. Tet T be the Earth, and *a b c d* a ring encompaſſing it at any diſtance, as Saturn's ring doth the body of that Planet.

Let *a b c*, the half of this ring turned towards the Sun S, be raiſed *above* the plane of the Ecliptic, and the other half *c d a*, be depreſſed below it. Then will the line A *a c* C be the *Line of the Nodes* of this ring.

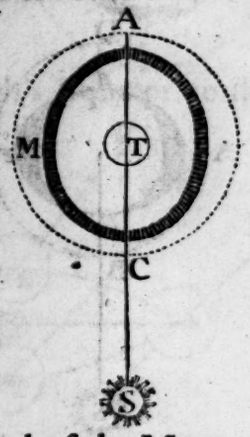
Let there be taken any indefinitely ſmall part, or particle of this ring M, and let the whole ring revolve about the center T, then will the particle reſemble the Moon in her orbit. And if the Nodes are in the Quadratures, as here, then will the Particle M be continually drawn downwards by the action of the Sun, ſo that inſtead of aſcending to *b*; it will only go to E; i. e. the Angle of Inclination of this Ring, to the Plane of the Ecliptic, will be leſs than it would have been without this action of the Sun.

Again, in the deſcent of this Particle downwards from E, being ſtill in the action of the Sun, its deſcent will be *haſtened*; and therefore, inſtead of going to *c*, as it would otherwiſe have done, it will cut the Plane of the Ecliptic in ſome other point nearer to B than *c*, as, e. g. at *e*.

But wherever this Ring cuts the Plane of the Ecliptic is the next Node, as was obſerved before with regard to the Moon. Therefore inſtead of A C, the *Line of the Nodes* will be F G, and the Nodes will have gone *backwards*.

If

If the points C and G be ſuppoſed continued to the orb of fixed Stars, the Star to which C pointed before, and which then lay in the line of the Ring's Node, will now appear diſtant from the line of its Node by the arch C G. That is, it will ſeem to have had a motion *forward*, owing to the motion of the Nodes of the Ring *backward*.

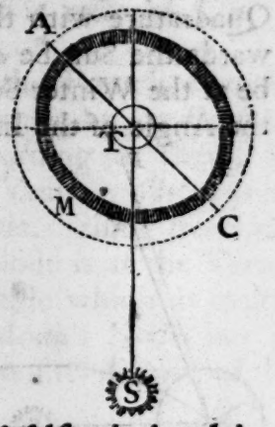


Let A C, the line of the Nodes of this Ring, be now in the Syzygies, or in conjunction with the Sun.

Since the Sun, S, is in the common interſection of the plane of the Ring with the plane of the Ecliptic, it will be in both thoſe planes, and therefore by its action, will not diſturb the particle M, or any other particle of the Ring, in its motion about the Earth, T; i. e. it will not affect the *inclination* of the *plane* of the *Ring*, to the *plane* of the *Ecliptic*, at all.

The Angle of the inclination of this Ring to the Plane of the Ecliptic, therefore, is *greateſt*, when the Nodes of it lie in the Syzygies.

The Nodes likewiſe are then at reſt, as before explained of the Moon.



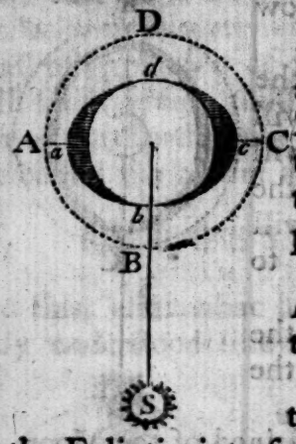
It is eaſy to apprehend likewiſe, that whatever hath been ſaid before of the Moon, when her Nodes are in the Octants, or any other ſituation whatever with reſpect to the Sun, will likewiſe hold good with regard to the particle M of this Ring, in the like ſituation of its Nodes as in the Figure here. So that nothing farther, in particular, needs to be offered on that ſubject.

What hath been explained above, with regard to this Ring, will hold good, whatever be its *thickneſs*, or whatever be its diſtance from the center of the Earth, T.

Let us now ſuppoſe that it *adheres* to the Earth itſelf; it is plain, it will not only have the motions above aſcribed to it, but will likewiſe make the body of the Earth *participate* of them along with it.

If, therefore, the line of the Nodes of this Ring, now *adhering* to the Earth, points to any fixed Star in the heavens, that line will have a ſlow motion *backwards*, in the very ſame manner as when we ſuppoſed that Ring before to encompaſs the Earth at a *diſtance*. This Ring is that redundency of matter already ſpoken of, whereby the Equatorial diameter of the Earth exceeds the Polar.

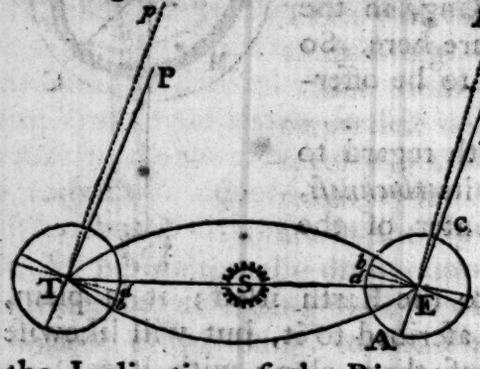
Since, therefore, the Equator cuts the Ecliptic every year, ſomething ſooner than it did the year before, the point of interſection in the heavens will have gone *backwards*. And as the Longitudes of the fixed Stars are reckoned from that point, they will *ſeem* to have gone *forwards*, and that, at the rate of one degree in ſeventy-two years.



By this motion of the Equinoctial points *backward*, the Axis of the Earth will make a ſlow revolution about the Axis of the Ecliptic, and the Pole of that Axis will deſcribe a ſmall circle in the heavens about the Pole of the Ecliptic, at the diſtance of twenty three degrees and a half. This revolution is compleated in 25920 years.

Let S be the Sun, *a b c d* the Earth's Equator. A B C D the Plane of the Ecliptic paſſing through the center of the Sun at S.

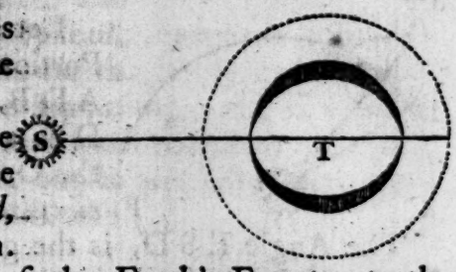
Let A C, the line of the Ring's Nodes, paſs thro' the Equinoctial points, becauſe there the Equator and the Ecliptic interſect each other. And if the Line of the Nodes be in Quadrature with the Sun, as here, and the part of the Ring turned towards the Sun be *elevated above* the Plane of the Ecliptic, the Sun S will be at the Winter Solſtice; and drawing the Point *b downwards*, will leſſen the Angle of the Inclination of the Equator to the Ecliptic; ſo that e. g. in the Figure below, inſtead of *b* E S 23° 29′ it ſhall be *d* E S only 23° 27′ and the Axis of the Earth, A C, inſtead of having the Situation A E P ſhall come into the Situation E *p*; that is, it ſhall have an Inclination, or NUTATION *towards the Sun*.



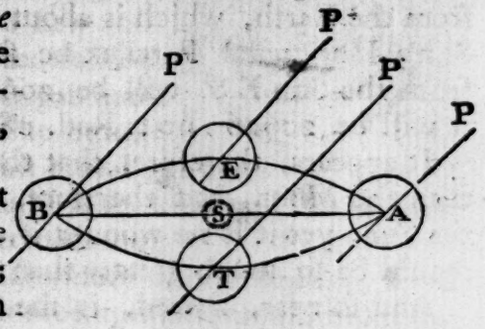
But if in the figure above, *a b c* is *below* the Plane of the Ecliptic, and therefore *below* the Sun, the Angle of the Inclination of the Ring to the Plane of the Ecliptic will, by the Sun's Action, be leſſened again, being, by that Action, drawn *upwards*. The Sun will be at the Summer Solſtice, and the Axis of the Earth, inſtead of having the Situation T P in the Figure here, will come in the Situation T *p*, i. e. it will have an Inclination, or NUTATION *from the Sun*. And the Angle *d* T S will be leſs than *b* T S.

If

If the Line of the Ring's Nodes paſſes through the Syzygies, the Sun S will be in one of the Equinoctial Points.



But in this Situation of the Line of the Ring's Nodes, the Inclination of it to the Plane of the Equator will not be *affected*, or *altered*, by the Action of the Sun. Therefore the Angle of the Inclination of the Earth's Equator to the plane of the Ecliptic, will be the *ſame* at *both* Equinoxes, and the Axis of the Earth at one Equinox, E, will be parallel to itſelf at the other Equinox, T, as here, E P, is parallel to T P.



Hence, therefore, it appears, that at the Winter Solſtice, A, the Axis of the Earth has a Nutation *towards* the Sun; That at the Summer Solſtice, B, it hath a Nutation *from* the Sun;

And that twice in the year, its parallèliſm to itſelf is reſtored, i. e. at the two Equinoxes.

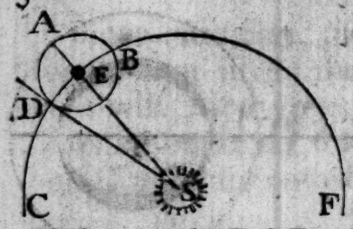
At the beginning of the year 1761, according to the French aſtronomers, * the obliquity of the Ecliptic, or the Angle made by the Equator and the Ecliptic was only 23° 28′. 17″. And, according to them, its mean Quantity decreaſes at the Rate of 47″ in 100 Years. There is an inequality, likewiſe, in the obliquity of the Ecliptic, ariſing from the action of the Moon. So that when the Moon's Node is at the Vernal Equinox, the obliquity of the Ecliptic, or the Angle which it makes with the Equator is *bigger* by 9″. And when the Moon's Node lies in the Autumnal Equinox, it is *leſſer* by 9″. This was firſt diſcovered by Dr. Bradley. †

The preceſſion of the Equinox hath hitherto been conſidered as cauſed by the Action of the Sun alone, but it is in reality cauſed by the joint actions of the Sun and Moon. And ſuppoſing the whole action to be 50″ 3 every Year, 14″ 5 Parts only muſt be aſſigned to the Action of the Sun, and the remaining 35″ 8 Parts to that of the Moon. Nor will this ſeem very ſurpriſing, if we conſider the Diſtance of the Sun, and the nearneſs of the Moon to our Earth. For, from what we know already of their Diſtances from us, to an Eye placed in the Sun, the *greateſt* Elongation of the Moon from the Earth will be but about 10 Minutes of a Degree.

Let

* In the Connoiſſ. des Temps, for that year.

†. See Philoſoph. Tranſact. No. 485.



Let S be the Sun, E the Earth, C D F, a Portion of the Earth's Orbit round the Sun; A D B, the Orbit of the Moon round the Earth. D S, a line drawn from the Sun, and touching the Orbit of the Moon in D, conſidered here as *circular*.

The Angle E S D, is the greateſt Elongation of the Moon from the Earth, obſerved from the Sun, ſuppoſing her to be at her mean Diſtance from the Earth, which is about 60 Semidiameters of the Earth. If the Sun's Horizontal Parallax be ſuppoſed 10″, the Diſtance of the Earth from the Sun E S, will be 20626 Semidiameters of the Earth. Then it will be 20626 : 60 :: Rad. : Sine of the Angle E S D, = 10′.

It appears, therefore, that the Sun is above 340 times farther from us than the Moon, and therefore, though ſhe is ſo much ſmaller than the Sun, yet it is no wonder if, on account of her nearneſs, her Effects ſhould be ſo much greater than thoſe of the Sun.

And ſo near, indeed, is the Moon to us in compariſon of the Sun, that, to conceive it the better, it may be remarked, that the proportion cannot be commodiouſly repreſented by any Orrery or Planetarium. For, from the Numbers above given, if we make the Diſtance of the Moon from the Earth only *one fourth* of an Inch, the Diſtance of the Sun from the Earth will be *ſeven feet*.

We have ſeen already in what manner the *Copernican* Syſtem was oppoſed and rejected. And one argument urged by *Riccioli* againſt it, as was ſaid, was, that did the Earth move in an *annual Orbit* round the Sun, there would be a difference obſerved in the *meridian Altitude* of a fixt Star in the ſame place of obſervation at *different ſeaſons* of the year. Becauſe the Earth would, upon this ſuppoſition, be nearer to the ſame fixt Star at *one* time of the year than *another*. This is called

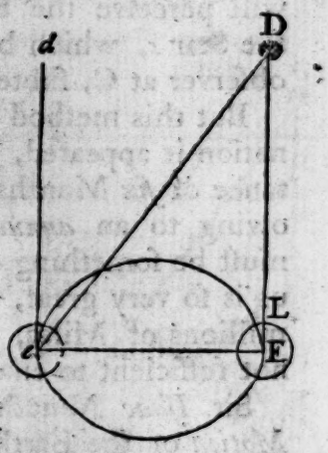
THE EARTH'S ANNUAL PARALLAX,

and is that Angle under which the Diameter of the Earth's Orbit would be ſeen from that fixt Star. This is true in theory. And this Angle would be diſcoverable, did the Diameter of the Earth's annual Orbit bear any ſenſible proportion to the diſtance of the fixt Stars.

This Angle, therefore, ſeveral Aſtronomers have ſet themſelves to diſcover, hoping, by that means, to eſtabliſh, by *direct obſervation*, the truth of the *Copernican* Hypotheſis. Amongſt the moſt celebrated of theſe was Dr. HOOKE, profeſſor of Aſtronomy at *Greſham* College, who with a Teleſcope, 36 feet in length, fixed in the roof of his houſe, obſerved the *bright Star* in the head of Draco, which paſſeth nearly over the vetrix of London.

Let

Let E be the Earth at the ſummer Solſtice, and L London. D the bright Star in Draco's Head, nearly vertical to it. Let *e* be the place of the Earth at the winter Solſtice. If the Earth hath an *annual motion* round the Sun, it is plain the Star which was vertical to London, when the Earth was at E, ought to be ſeen diſtant from the Vetrex, when the Earth is at *e*, by an Angle as *d e* D = *e* D E.



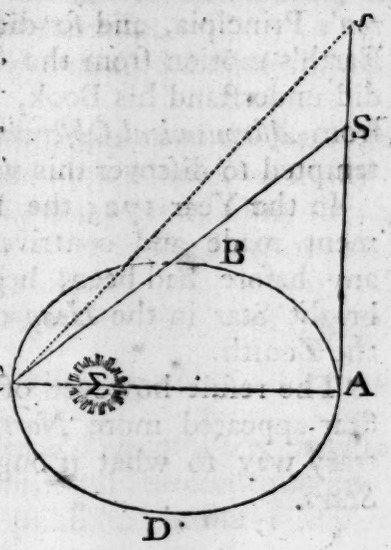
This Angle he determined to be 27″, or 30″, at the moſt.

His Book upon this ſubject was publiſhed A. D. 1674. And if we take his Parallax of 30″, we ſhall find the Diſtance of that Star from us to be equal 6875 Diameters of the Earth's annual Orbit round the Sun.

But this obſervation of Dr. *Hook*, though long eſteemed to be very accurate, yet was afterwards found to be erroneous.

Mr. *Flamſteed*, in poſſeſſion of the obſervatory at *Greenwich*, fixed the Arch of a Circle to a Wall, in order to obſerve whether the Pole Star had any Parallax. And the reſult of *ſeven* Years continued Obſervations was, that he concluded it had a Parallax of about 40″, or 45″, at the *moſt*. But theſe obſervations are not to be depended on, as it is hardly probable that the Wall itſelf to which he fixed his inſtrument, ſhould remain exactly in the ſame poſition, in all its parts, from one Solſtice to another.*

As *Caſſini* had obſerved ſeveral Sars to appear *double*, or *triple*, at one Time, and *ſingle* at another; as the *firſt* Star of Aries, the Star in the Head of the *firſt* of Gemini, the Star in the *Sword* of *Orion*, and ſome of the Pleiades, ſome perſons entertained great hopes of making an advantage of ſuch Obſervations as theſe, in determining the Parallax of the *fixt ſtars*. And the more ſo, as ſuch an Obſervation doth not depend upon the fixing an inſtrument to an immovable point, nor doth it require any other Apparatus than a Teleſcope fitted with a Micrometer.



Let A B C D be the Orbit of the Earth about the Sun Σ, and let S, *s*, be two Stars lying in the ſame ſtreight line A S. An obſerver at A will look upon thoſe *two* Stars as *one*. But the ſame obſerver removed from A to C,

* His Letter to Dr. Wallis upon this Subject is publiſhed in the third Vol. of Dr. Wallis's Works, page 701.

will perceive the Star S to be *double*. That is, he will now perceive the Star *s*, which before lay hid behind the Star S, the two Stars to the obſerver at C, ſubtending the Angle S C *s*.

But this method fails as well as the former. For upon farther examination it appeared, that theſe Stars were not *ſingle* and *double* at the Diſtance of *ſix* Months, as they ought to have been, was this Phenomenon owing to an *annual Parallax*. The Cauſe therefore, whatever it is, muſt be ſomething elſe. And, indeed, the Diſtance of the fixt Stars from us is ſo very great, that the removal of the Earth from its Place by 160 millions of Miles, nearly the Diameter of the Earth's annual Orbit, is not ſufficient to enable us to diſcover a Star lying behind another.

Sir *Iſaac Newton* was the firſt perſon who *demonſtrated* the *annual Motion* of the Earth. But this he did from the Laws of Gravity, and not by *Aſtronomical Obſervations*. He was very cautious of giving credit to ſuch obſervations as thoſe from which others deduced an annual Parallax of the fixt Stars.

And when Mr. *Rowley* had ground an *object* glaſs to be fixed in one of the Towers of St. *Paul*'s Church, at the top of the Newel of the Stair-Caſe, which would ſerve as a very long Teleſcope to obſerve the Stars near the Zenith, in order to determine their Parallax, he would never conſent to its being put up. For as the Building in ſettling might alter the ſituation of this Teleſcopic Tower, he was afraid leſt Concluſions ſhould be drawn, in ſo nice a point, from *precarious* and *uncertain Obſervations*.

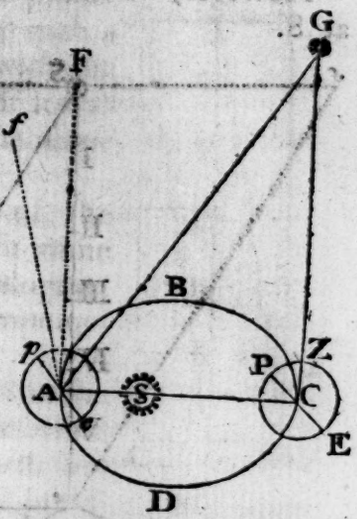
However, as many learned men did not underſtand Sir *Iſaac Newton*'s Principia, and ſo did not perceive the force of his proof of the Earth's motion from the Laws of Gravity; and as many others, who did underſtand his Book, were yet willing to have a collateral proof from *Aſtronomical Obſervations*, ſeveral perſons, ſince that time, have attempted to diſcover this way, a Parallax of the *fixt Stars*.

In the Year 1725 the Hon. *Samuel Molyneux*, Eſq; with an inſtrument made and contrived by Mr. *Graham*, much more accurate than any before had been, began to obſerve, along with Dr. *Bradley*, the bright Star in the *Head* of Draco, by *Bayer* marked γ, as it paſſed near the Zenith.

The reſult however of *many* and *accurate obſervations* was, that the Star appeared more *Northerly* in December than in June, juſt the contrary way to what it ought to be from the *annual Parallax* of the *fixt Stars*.

For

For let A B C D be the annual Orbit of the Earth, round the Sun S; and let P E be the Axis of the Earth at the *Summer Solſtice*, and *p e* the Axis of the Earth at the *Winter Solſtice*; and let G be the bright Star γ in the head of *Draco*, vertical to the place Z, making with the Axis of the Earth produced the Angle P C G.



When the Earth comes to the Winter *Solſtice* at A, *it is plain*, that if there was any *annual Parallax* of that Star G, it would be ſeen by an Obſerver at A along the Line A G, making with the Axis of the Earth *p e*, parallel to P E, the Angle *p* A G greater than *p* A F, and therefore greater than P C G.

Therefore the Star G in *December* ought, upon ſuppoſition of a *Parallax*, to appear farther diſtant from the Pole, or more ſouthерly than in *June*.

But on the contrary, theſe Obſervers found that the Star G, inſtead of appearing in *December* along the Line A G, in *reality* appeared along the Line A *f*, making the Angle *p* A *f* leſs than *p* A F, or its equal P C G, i. e. inſtead of appearing more to the *South* in *December* than in *June*, as it ought to have done, ſuppoſing a *Parallax*, it appeared more *Northward*, or nearer to the Pole.

Whatever therefore was the cauſe of ſo ſtrange an appearance, it is plain, it could not be attributed to an *annual Parallax*.

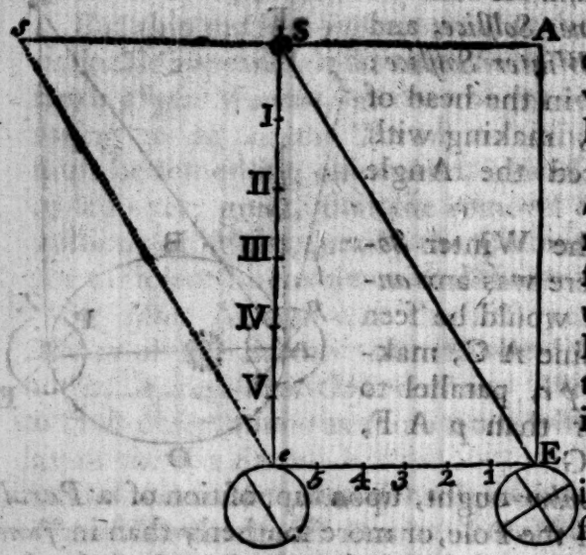
This ſurprized the Obſervers, and Mr. *Malyneux* died before the cauſe was diſcovered.

After his death, Dr. *Bradley*, with another inſtrument of the ſame kind, made alſo by Mr. *Graham*, obſerved the ſame appearances, not only in that, but ſeveral other Stars. And being, by many trials, fully ſatisfied that the Phenomenon was not owing to any error in the Inſtrument, he conſidered what might be the cauſe, and concluded, that it was really owing to the *Motion* of the *Earth*, and the *progreſſive Motion* of *Light*.

This Diſcovery was made in the Year 1728.

Thoſe that underſtand *Aſtronomy* and *ſpherical Trigonometry*, may read Dr. *Bradley*'s own account of his Obſervations, and the conſequences he draws from them, in a letter to Dr. *Halley*, publiſhed in the *Philoſophical Tranſactions*, No. 406.

However, to make the thing as clear as poſſible, let us ſuppoſe a Star at S.



From this, let Light be propagated every way in right Lines. But we will only here conſider two of thoſe Rays, or Lines, as S E and S *e*.

E *e* is a right Line joining the *Solſtices*, and conſidering the immenſe diſtance of the fixt Stars from the Earth, it may be looked upon as the Line in which the Earth with the Obſerver, is carried; the Curvature of its Orbit not being diſcernable.

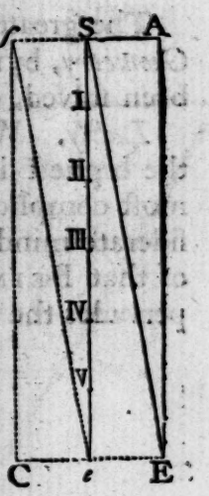
Let us farther ſuppoſe that Light is propagated with a Motion only ſix times ſwifter than the Motion of the Earth; ſo that a particle of Light ſhall go through the Line A E or S *e*, in the ſame time that the Earth goes through the Line E *e*, which is here drawn too large for diſtinction ſake.

It would follow then, that whilſt a particle of Light goes through any part of the Line S *e*, as, e. g. S. I, I. II, II, III, &c. the Earth will go through a correſpondent part of the Line E *e*, as E. 1, 1. 2, 2. 3, 3. 4, &c.

Now if the Earth was at reſt at E, or *e*, an Obſerver from it would ſee the Star in the Line S E, or S *e*, by means of the particle of light which would come from S to E, or *e*, but he would never ſee the Star in the Line *s e*, as if it was at *s*.

But if we ſuppoſe the Earth ſetting out from E to deſcribe the Line E *e*, at the ſame that time the two particles of light ſet out from the Star S, the to move in the Line S E, and the other to move in the Line S *e*, it will one follow, that the Earth will have left the point E, before the particle of light coming in the Line S E can be arrived at the Obſerver's eye, which will be at *e*, when that is at E.

But then the other particle of Light coming in the Line S *e*, will ſtrike the Obſerver's eye juſt as it reaches *e*. For, becauſe of the immenſe diſtance of the fixt Stars, the Lines S E and S *e*, may be looked upon as *equal*.



But though that particle of light, by its own proper motion along the Line S *e*, would ſtrike the eye at *e*, with a perpendicular ſtroke, yet becauſe the Earth, along with the Obſerver comes to the point *e* with ſuch a velocity as if it was continued, would carry it along *e* C = E *e* in the ſame time that it deſcribed E *e*.

Therefore, on account of theſe joint motions of the Earth, and ray of light, it will ſtrike the eye, as if it came along *ſ e*, deſcribing the *Diagonal* of the Parallelogram S *c*, C *ſ*, as, it is well known, is the caſe in all compound Motions.

Since the motion of Light is 10210 times ſwifter than the motion of the Earth in its annual Orbit; and light deſcribes the Line S E, or S *e*, in the ſame time that the Earth deſcribes its Semi-orbit, here denoted by the right Line E *e*, it is plain that the Line S E will be 10,210 times longer than the Line E *e*. The Line E *e* is now eſtimated at 160 millions of miles. The Line S E muſt therefore be 10,210 times as great; that is, it will be 1643810000000 miles, or one million ſix hundred, forty three thouſand, eight hundred and ten millions of miles. And as the fixt Stars do not ſeem to be all of them placed in one concave ſurface, there is reaſon to think there may be many of them placed at a much greater diſtance from us, and from one another, than this. A thought too great for the human mind, and fit only for the contemplation of beings whoſe faculties are ſuperior to ours.

This is now commonly called by Aſtronomers,

THE ABERRATION OF LIGHT;

Becauſe from hence it is manifeſt that the *apparent* places of the fixt Stars, are different from their *true* places. A diſcovery that doth honour to the inſtrument by which it was made, and more to the Obſerver, who drew the concluſion.

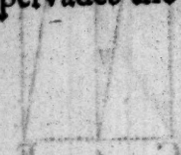
In this manner, then, have we been able to trace the progreſs of Aſtronomy, from its earlieſt infancy, to its preſent perfection, during the ſpace of 4000 years. In the courſe of this deduction, it hath appeared, that it is not a Science of mere uſeleſs ſpeculation, but that, without it, we ſhould know little or nothing of the Earth we inhabit, whether we reſpect remote *diſtances*, or the date of very *ancient tranſactions*.

We have ſeen in what manner each former diſcovery hath paved the way to a ſucceeding improvement, till the whole hath grown up to one uniform beautiful ſyſtem.

The

The greateſt improvements in this Science have been found owing to *Geometry*, by means of which, difficulties, otherwiſe unſurmountable, have been ſolved, effects explained from cauſes *ſimple*, *conſtant*, and *adequate*.

Laſtly, We have ſeen, that in every part of the material World, are the higheſt inſtances of regularity and conſiſtency, and that even in the moſt complicated caſes. All which cannot fail of impreſſing, upon conſiderate minds, the ſtrongeſt ideas of the Wiſdom, Power, and Goodneſs of that BEING, that formed at *firſt*, and *ſtill* preſerves, conducts, and pervades the Univerſe.



FINIS.

ERRATA.

Page 17, line 1, for *quainted*, read *unacquainted*.
19, line 8, dele *p*, in *Sempt*, and in *Assempt*.
39, line 2, dele I. Line 8, dele II.
53, line 32, dele I.
59, line 9, for *Goold*, read *Gold*; and l. 31, for אבבא, read אבנא
63, line 29, for *Calameta Prita*, read *Calamita Preta*.
161, line 12, for *Refraction*, read *Reflection*.
168, line 17, for *make*, read *made*.
265, line 36, before the word *Time*, insert *that*.

ERRATA.

Page 17, line 1, for quainted, read unacquainted.
19, line 8, dele p, in Sempr, and in Alempr.
39, line 2, dele I, [illegible] 8, dele II.
53, line 32, dele [illegible]
59, line 9, for C[illegible]d, Gold; and l. 31, for NJJN, read NJJN
63, line 25, for California Trifa, read California Trifa.
101, line 12, for Refraction, read Reflection.
168, line 17, for make, read made.
265, line 35, before the word Time, insert that.